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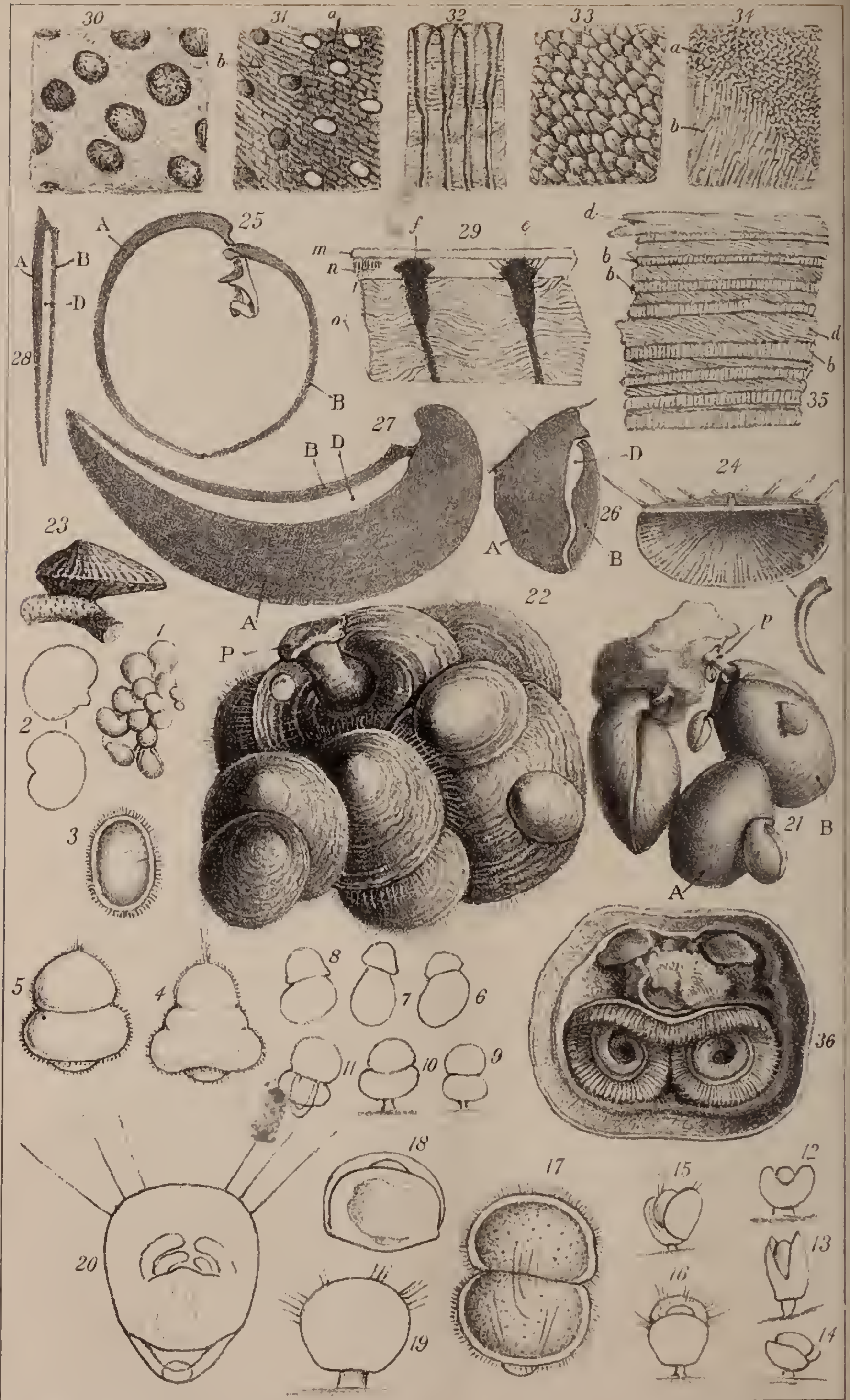

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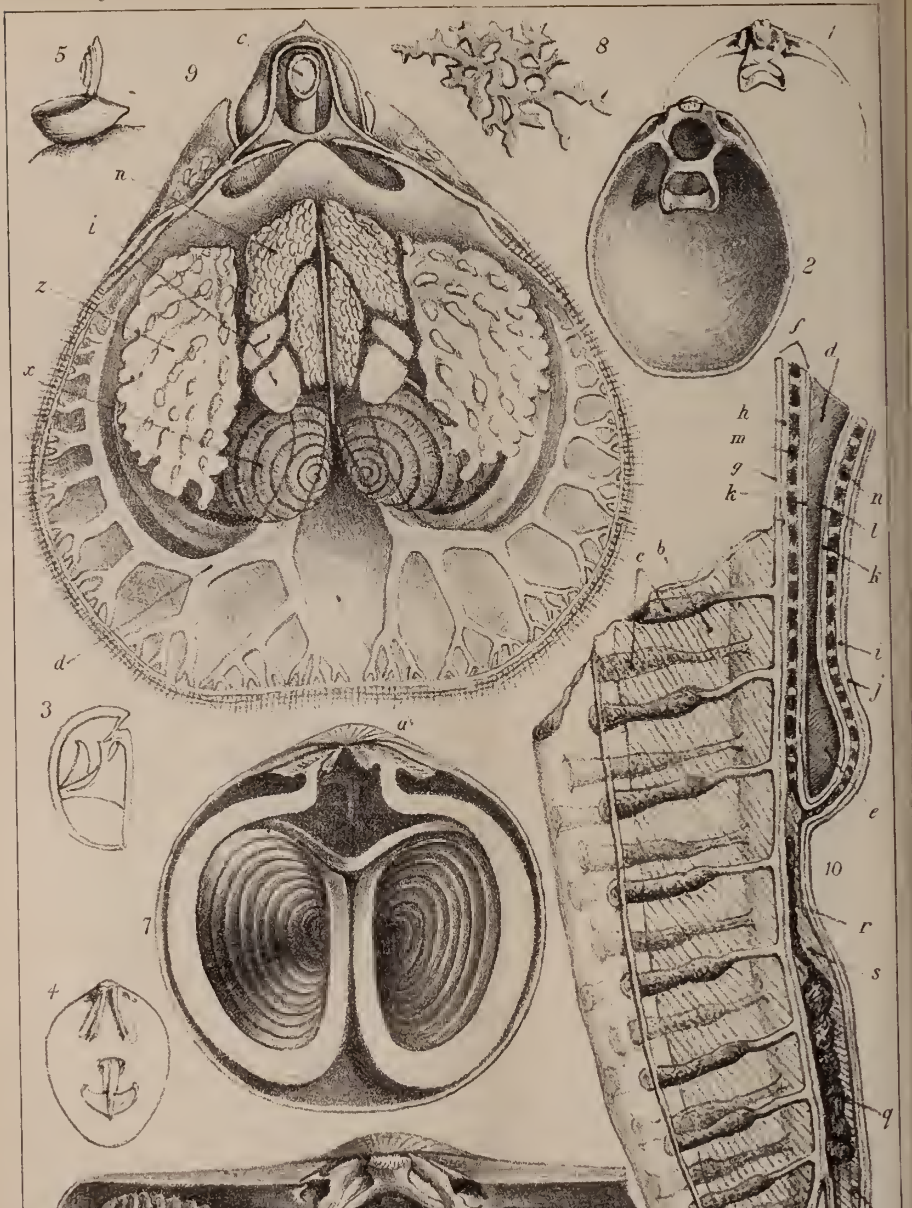
BRACHIOPODA.



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ORIGINAL ARTICLES.

I.—WHAT IS A BRACHIOPOD?[1]

By THOMAS DAVIDSON, F.R.S., F.G.S., V.P.P.S., etc.

PART I.

(PLATES VII. AND VIII.[2])

WE are all aware that it is very often much easier to put a question than to obtain an entirely satisfactory answer, and I am consequently sorry to have to begin my few observations on a very extensive class or group of organisms, by stating that zoologists and comparative anatomists have not yet entirely agreed as to the exact position it should occupy among invertebrate animals.

The first species belonging to the class were imperfectly and quaintly described and figured by Fabio Columna as far back as 1606, and for many years were supposed to be referable to the genus *Anomia*, one of the *Lamellibranchiata*; but as was judiciously observed by Edward Forbes, "A close examination shows that there is no relationship between them, but only a resemblance through formal analogy." It is during the present century that the class itself has been worked out and understood, and this has been achieved after the most lengthened and persevering researches.

It will not be possible in a short article to enter upon a complete history of the progress made by science up to the present time with respect to the Brachiopoda. Suffice it to say, that many of the most eminent zoologists and palæontologists have materially contributed to our knowledge of the group, and I have devoted the best portion of my life to its elucidation. We may however observe that, previously to the present century, several naturalists had published notes of some interest upon the Brachiopoda, which have helped to bring the subject under the special notice of the more experienced malacologists of our time. In 1675, 1687, and 1688, Martini Lister published figures of a few recognizable species of Brachiopoda, and in particular of *Productus giganteus*. In 1696 Llhwyd proposed the name *Terebratula* for several of the shells that had previously been referred to *Anomia*: he also gave some good figures of several species of Brachiopoda found in the neighbourhood of Bath. In 1773 T. Pennant described and figured some of the soft parts of the animal of *Terebratulina caput-serpentis* (especially its brachial or labial appendages), and in 1774 Grundler gave a good description of the same appendages with enlarged illustrations. Again, in 1776 and 1791, Müller and Poli described the animal of *Crania* (their *Patella anomala* and *Criopus turbinata*) with some enlarged illustrations, in which the brachial appendages are correctly represented.[1] During that century many species of Brachiopoda both recent and fossil were described and figured by Linnæus, Bruguière, and others, but no attempt at classification was made.

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[1] This memoir is the substance of a lecture delivered by the author to the Brighton and Sussex Natural History Society on the 11th of February, 1875, and subsequently published in French with additions and plates in vol. x. of the Annales de la Société Malacologique de Belgique for 1876.

[2] Plates IX. and X. will accompany Part II.

Space unfortunately will not admit of my mentioning in detail the honoured names of all those who have so materially contributed to the knowledge we at present possess with reference to the Brachiopoda; but we must allude to Von Buch, Alcide d'Orbigny, Defrance, de Blainville, de Verneuil, S. P. Woodward, Gray, Deslongchamps, father and son, Sowerby, Barrande, de Koninck, King, Salter, E. Suess, M'Coy, Hall, Billings, Dall, Dalman, Fischer, Pander, Moore, Eichwald, Kutorga, Keyserling, Sandberger, Seguensa, Meek, etc. The names of the zoologists who have so ably worked out the anatomical and structural characters of the animal will be duly recorded in the sequel. Grundler, in 1774, seems, however, to have been the first to propose to create for the animals under notice a distinct class among the Mollusca.

Name.—The name Brachiopod (*βραχιων*, an arm; *ποῦς*, *ποδος*, a foot) was proposed for the class by Cuvier in 1805, and Dumeril in 1809, and has since been very extensively adopted. In 1824 Blainville proposed as a substitute for Cuvier's name that of Palliobranchiata (*pallium*, a mantle; *branchiæ*, gills), on account of the respiratory system being combined with the mantle on which the vascular ramifications are distributed. This term has always been adopted by Prof. King, who perhaps has rightly objected to Cuvier's name, on the grounds that it is a misnomer; for the two variously curved and cirrated brachial or labial appendages, improperly designated as arms or feet, were subsequently found not to subserve the function of locomotive organs.

Shell.—Before alluding to the position the Brachiopod should occupy amongst the Invertebrata, we may at once observe that the animal is protected by a shell composed of two distinct valves; and that these valves are always, except in cases of malformation, equal-sided, but not equi-valved. The shell is likewise most beautiful in its endless shapes and variations; in some species it is thin, semi-transparent and glassy, in others massive; generally the shell is from a quarter of an inch to about four inches in size: but in certain species it attains nearly a foot in breadth by something less in length, as is the case with *Productus giganteus.* The valves are often very unequal in their respective thickness, as may be seen in *Productus Llangollensis* (Pl. VII. Fig. 27); *Davidsonia Verneuili* (Pl. VII. Fig. 26), etc.; and while the space allotted to the animal is very great in a number of species, as in *Terebratula sphæroidalis* (Pl. VII. Fig. 25), it is extremely small in many others, as *Strophomena* and *Leptæna* (Pl. VII. Fig. 28). The outer surface of many of the species presents the most exquisite sculpture, heightened by brilliant shades, stripes, or spots of green, red, yellow, and bluish-black.

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[1] A very remarkable paper by M. de Lamanon, "Sur les Térébratules ou Poulettes, et déscription d'une espece trouvée dans les mers de la Tartarie Orientale," was published in 1797 in vol. iv. of the Voyage de la Pérouse autour du monde. In this memoir, which appears to have been overlooked by all those who have treated of the same subject, the author describes as far as his knowledge permits the soft parts of the animal of a species of *Terebratella.*

The valves have been distinguished by various names, but those of *dorsal* and *ventral* are in more general use. The ventral valve is usually the larger, in many genera as *Terebratula* and *Rhynchonella*, it has a prominent beak, with a circular or otherwise shaped perforation or foramen at or near its extremity, partly completed by one or two plates termed a deltidium. Through the foramen passes a bundle of muscular fibres called the peduncle, by which the animal is in many species attached to sub-marine objects during at least a portion of its existence. It is, however, certain from the admirable researches of Prof. Morse that the embryo of some, if not of every species, swims most actively in every direction and turns abruptly about; but that in the fourth stage of its development it becomes *attached*, the peduncle widening at its end into a sucking disk. Other species show no indication of ever having been attached; while some that had been fixed by means of a peduncle during a part of their existence become detached at a more advanced stage of life, the opening for the peduncle becoming gradually cicatrized. Lastly, forms appear to have adhered to sub-marine objects by a larger or smaller portion of the surface of their ventral valve, or by spines (*Strophalosia*, etc.), during their entire life.

In external shape the valves are essentially symmetrical (differing in this respect from those of the *Lamellibranchiata*), so much so, that certain Brachiopod shells received the name of *Lampades* from some early naturalists; but while such may bear a kind of resemblance to an antique Etruscan lamp, by far the larger number in no way resemble one. The valves are either articulated by means of two curved teeth developed from the hinge-margin of the larger valve, and fitting into sockets in the corresponding part of the smaller one, or they are unarticulated, and kept in place by means of muscles especially provided for that purpose.

Having described the exterior of the shell, a few words may now be devoted to its interior. On the inner surface of both valves several well-defined muscular impressions are observable, which vary considerably in position and shape in different genera and species. They form either indentations of greater or lesser size and depth, or occur as variously shaped projections. In the *Trimerellidæ* some of the muscles are attached to a massive or vaulted platform situated in the medio-longitudinal region of the posterior half or umbonal portion of both valves. In addition to these, there exists in the interior of the dorsal valve of some genera a variously modified thin, calcified ribbon-shaped lamina or skeleton for the support mainly of the brachial or labial appendages; and so varied, yet constant in shape to certain species is this laminal apophysis that it has served as one of the chief characters in the creation of both recent and extinct genera (Pl. IX. Figs. 2, 7, 9). The apophysis, or loop, is more or less developed, extending in some genera to upwards of three-fourths of the length of the shell, but in others it is so short and rounded as to project only a little beyond the hinge. In some genera it is attached only to the hinge-plate, as in *Terebratula, Waldheimia* (Pl. IX. Fig. 2), in others to a central longitudinal plate or septum[1] (Pl. IX. Fig. 9). In certain families the apophysis presents the form of two spiral processes which nearly fill the interior of the shell, the ends of the spires being either directed outwards towards the cardinal angles (*Spirifer*, Pl. VIII. Fig. 6), or placed horizontally with their apices directed inwards and towards the centre of the concave surface of the same valve, which they almost fill; the inner sides of the spires are pressed together and flattened with their terminations close to each other near the centre of the bottom of the shell (*Atrypa*, Pl. VIII. Fig. 7). In the *Rhynchonellidæ* again it assumes the shape of two short, slender, curved laminæ (Pl. IX. Fig. 7); while in many genera and even families, *Productidæ,* etc., there exists no calcified support for the labial appendages.

The muscles, pallial sinuses, and ovaries, generally leave such indentations on the internal surface of the valves, in both recent and fossil genera and species, that they materially assist in determining the characters of extinct forms; and in addition, the brachial or labial appendages often leave indications of their presence and character, which is also evinced by the shape of the calcified skeleton which supported them to a greater or lesser extent.

Shell Structure.—The structure of the shell has been shown by Dr. Carpenter, Prof. King, Dr. Gratiolet and others to be generally distinct from that of the Lamellibranchiata or Gasteropoda. Dr. Carpenter, who has described the shell structure with infinite care and minuteness, informs us that in the shell of the Brachiopoda, there is not that distinction between *outer* and *inner* layers, either in structure or mode of growth, which prevails among the ordinary bivalves; and that it seems obvious, both from the nature and form of the shell substance, the mode in which it is extended, that the whole thickness of the Brachiopod shell corresponds with the outer layer only of the Lamellibranchiata. He adds that he has, however, occasionally met with a second layer in recent *Terebratulæ,* within the earlier formed portion of the shell, but confined only to a part of the surface, instead of extending beyond it. In some families, according to Prof. King, it consists of three divisions; the innermost and middle divisions, which constitute the entire thickness of the valve, are calcareous, with a prismatic or fibrous structure, while the outer division consists of a very thin membrane (Pl.VII. Fig. 29). The innermost and intermediate divisions are in some families traversed by minute tubular canals which pass from one surface to the other, for the most part in a vertical direction, and at tolerably regular intervals; but just before terminating, near the outer surface of the epidermis, their orifices suddenly become dilated; the lower half of the canals being often considerably smaller in diameter than the upper half. The canals are occupied by cœcal processes proceeding from the mantle, or the fleshy covering of the animal. Their functional nature is according to Dr. Carpenter branchial or subservient to respiration; but, as observed by Prof. King, the outer epidermis, which covers their expanded terminations, would seemingly prevent any communication between the surrounding sea-water and the mantle; so that it may be questioned whether they are at all connected with the respiratory function. In certain genera, such as *Rhynchonella,* there are no canals; the shell being found to consist of flattened prisms of considerable length, which lie parallel to one another with great regularity, and at a very acute angle to the surface of the valves. The shell substance of *Lingula* Prof. King believes to be also almost entirely composed of Keratode, with a subordinate portion of phosphatic calcareous matter.

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[1] In a very interesting paper on the development of the loop in *Wald. cranium* and *W. septigera* entitled "Bidrag til Vestlandets Molluskfauna," published in the "Saerskilt Aftryk af Videnskabsselskabets Forhandlinger" for 1875, Mr. Herman Friele has started the hypothesis that the loop becomes modified with age, and he indicates a most remarkable development of a simple loop out of a compound one, but before this important question can be definitely settled a complete connecting series of the different ages of a same species will have to be examined, which has not been hitherto done to my entire satisfaction.

The shell structure of *Lingula* and *Discina* has also been attentively studied by Dr. Gratiolet in his excellent memoir "Etudes anatomiques sur la *Lingula anatina,*" 1860. Therein he mentions, that "the structure of the valves in the *Lingulidæ* appears at first sight to differ much from that of the *Terebratulidæ,* but a more attentive examination reveals analogies at first unsuspected. Two distinct elements exist in the shell of *Lingula*—the one corneous, and the other testaceous. They occur in thick layers alternating from the convex to the concave surface of the valves, commencing with a superficial corneous one. These layers are not, however, of equal thickness throughout. On the convex side the thickness of the horny layers is greater towards the outer surface of the shell, while on the visceral, or inner surface, the testaceous elements predominate. They are of especial thickness at the level of the posterior angle of the rhomb. The thick testaceous layers are separated by thin corneous ones which thin out at certain points. This arrangement gives an amount of opaqueness to the central portions of the valves, while the outer edges, where the horny substance predominates, are semi-transparent. The structure of the testaceous layers simulates that of the *Terebratulidæ;* they are crossed by numerous microscopic canals which are traversed by extremely delicate striæ, recalling the chains formed by the prismatic elements of the shell in *Terebratulidæ.* This description applies equally to *Discina,* but in these last the calcareous portion predominates greatly over the horny one."

Soft Parts of the Animal.—I must now allude to some of the soft parts of the animal, but it would require much more space than can be bestowed in this short article to do anything like justice to so difficult a subject. I am, however, truly happy to state that this important inquiry has been most ably and successfully elaborated during the last forty years by some of the most distinguished anatomists and naturalists of the period. To such men as Hancock,[1] Cuvier,[2] Owen,[3] Huxley,[4] Gratiolet,[5] Vogt,[6] Macdonald,[7] King, and others, we are indebted for an extensive series of dissections and observations which have defined, to a very considerable extent, what are the true characters of the Brachiopod; while some important researches elaborated by Steenstrup, Lacaze-Duthiers, Morse, Dr. Fritz Müller, Oscar Schmidt. McCrady, Kowalevsky, and others, have thrown much additional light upon the embryology and early stages of the group. Some differences in opinion, it is true, have been and are still entertained with respect to the exact function to be attributed to certain parts of the animal; but on all essential questions there is a pretty general agreement.

Before describing the various parts of the animal, it may be as well to mention that the Brachiopods have been divided by Bronn into two great groups, termed *Apygia* and *Pleuropygia*. Professor King, considering these to be inadmissible on certain grounds, substituted the name *Clistenterata* for the first group, on account of its including animals that are destitute of an anal aperture; and the term *Tretenterata* for the second, as it embraces animals provided with this opening. The former division contains species which have the valves articulated, as *Terebratula*, *Spirifer*, *Rhynchonella*, etc. The latter comprise species with non-articulated valves, as *Lingula*, *Discina*, etc.[8] Some very important modifications in the animal are connected with these two divisions, especially in what relates to the muscular system.

According to Morse the Brachiopods are reproduced by eggs, generally kidney-shaped and irregular, which are discharged from the anterior margin of the shell, and drop just beyond the pallial membrane, hanging in clusters from the setæ. Some uncertainty has prevailed as to whether there is a male and female individual. Lacaze-Duthiers and Morse state that the sexes are separate, and describe them as such in *Thecidium* and *Terebratulina*, and the French malacologist goes so far as to suggest that a difference is even observable in the shell; but this point I am unable to determine.

Prof. Morse describes the embryo of *Terebratulina* with great minuteness during its six stages of development. It is divided into two, three, or four lobes clothed with vibratile cilia; and before becoming attached swims, or whirls head foremost, by means of the vibratile cilia covering the body. Morse describes the gradual formation of the shell from its first stage of development to the adult condition. Lacaze-Duthiers also alludes to two and four eye-spots in the embryo of *Thecidium*, and states that the animal appears to be in some measure sensible to light. The mouth conducts by a narrow œsophagus to a simple stomach, which is surrounded by a large granulated liver. Owen's "hearts" have been found to be oviducts, while the true heart would, according to Huxley and Hancock, consist of a pyriform vescicle appended to the dorsal surface of the stomach; but Prof. Semper, who has described the animal of *Lingula* at considerable length, with especial reference to its vascular system, contends that the pyriform vescicle termed "a heart" does not represent that organ, that there is not the least vestige of vascular system connected with it, and consequently that the existence of a heart must be considered unproven. The digestive organs, viscera, as well as the muscles, which take up only a small place in the proximity of the beak, are separated from the great anterior cavity, and protected by a strong membrane, in the centre of which the mouth is situated. The nervous system consists of a principal ganglion, of no great size.

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[1] Philosophical Transactions Royal Society, vol. 148, 1858.

[2] Sur l'animal des Lingules, Bull. Soc. Philomatique de Paris, vol. i., 1797, and Sur l'animal de la *Lingule anatina*, Mémoirs du Museum, vol. i., 1802.

[3] Transactions of Zool. Soc., vol. i., 1833, and Davidson's General Introduction to British Fossil Brachiopoda, vol. i., 1853.

[4] Annals and Mag. of Nat. History, vol. xiv., 2nd series, 1854.

[5] Journal de Conchyliologie, 1857, 1859, and 1860.

[6] Anatomie der *Lingula anatina*, 1845.

[7] On the Physiology of the Pallial sinuses of the Brachiopoda, Transactions of the Linnæan Society of London, vol. xxiii., p. 373, 1862.

[8] An instructive note on the primary divisions of the Brachiopods by T. Gill will be found in the Annals and Mag. of Natural History, 4th, series, vol. xii., 1873.

Mantle.—Both valves are lined by a delicate membrane termed the "pallium" or mantle; it secretes the shell, and is generally fringed with horny bristles or setæ (Pl. VIII. Figs. 9 and 10). It is composed of an outer and inner layer, between which are situated the blood-channels or lacunes. The mantle has been ably described by Hancock, and by E. Deslongchamps,[1] who observes "that all the internal parts of the shell are lined by the internal layer of the mantle, with the exception of the muscular impressions, or those portions where the muscles are inserted on the inner surface of the shell."

The outer layer closely lines the inner surface of the valves to which it adheres, and in those species in which the shell is traversed by canals there exists on the surface of the mantle facing the inner surface of the valves, corresponding short cylindrical membranous projections, or cæca, which insert themselves into the small tubular orifices that traverse the shell (Pl. VIII. Fig. 10*c*). The cæcal prolongations do not exist in those genera such as *Rhynchonella* where the shell is deprived of tubular perforations. The inner layer is rather thicker than the outer one, and is covered with vibratile cilia. Between the two layers composing the mantle are situated the blood-channels or lacunæ. These vary in their dispositions or details in different genera, and as they project to some small extent, leave corresponding indentations on the inner surface of the shell, so that their shape and directions can, very often, be traced on fossil and extinct genera, as well as if the animal were still living, as may be seen in the numerous illustrations appended to my works on British and Foreign Brachiopoda.

There are usually four principal arterial trunks in each lobe of the mantle; the two central ones run direct to the front, near to which they bifurcate, while the outer ones give off, at intervals, on the side facing the lateral margin of the valves, a series of branches which bifurcate several times, as may be seen in the figures here reproduced from Hancock's admirable work (Pl. VIII. Fig. 9, Pl. X. Fig. 4). That eminent zoologist observes that the inner lamina of the mantle, and more particularly that portion of it forming the floor of the great pallial sinuses, undoubtedly assist in purifying the blood.

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[1] Recherches sur l'organisation du Manteau chez les Brachiopodes articules, Caen, 1864, and to which the reader is referred for further details.

In 1854, in his review of my Monograph on British Fossil Brachiopoda, Oscar Schmidt called attention to an important anatomical omission, namely, the existence of a vast number of microscopic flattened, calcareous, denticulated plates or spiculæ on certain parts of the surface of the mantle, which serve, no doubt, to stiffen the portions that contain them. It was, moreover remarked by Hancock, and afterwards by Deslongchamps, that these calcareous plates "are not spread over the entire surface of the mantle, but only over the large vascular sinuses, the arms, and the perivisceral cavity." These spiculæ do not, however, appear to be present in every species, being totally absent in *Lingula, Rhynchonella,* etc.; but Deslongchamps again observes that, "after an examination of the genera *Kraussina, Terebratula, Terebratulina, Megerlia* and *Morrisia* (*Platidia*), we find a series in which the number and consistency of the calcareous portions increase in a very rapid manner, the spicules forming several layers, leading the observer by a series of gradations to the genus *Thecidium,* in which the spicules are soldered together, occupying the whole of the mantle, and incrusting it to such an extent that the mantle is no longer distinguishable from the shell itself. The mantle forms that calcareous mass, which equals in consistency the brachial appendages, a fact of which palæontologists have often, and in vain, sought the explanation."

The Brachial or Labial Appendages are a pair of singular organs eminently characteristic of the Brachiopoda. They are often, more correctly, termed *labial* appendages on account of each member being a prolongation of the lateral portion of the lips or margin of the mouth. The lamellibranchs, or conchifera, have analogous appendages, but very much less developed. They assume different shapes in different genera, and are supported, or otherwise, by the more or less complicated calcified skeleton already described. The brachial or labial appendages, whether they form a pair of long, bent, or spirally convoluted organs, occupy the larger portion of the cavity of the shell, in front of the visceral chamber; they therefore are mainly composed of a membranous tube fringed on one side with long flexible cirri (Pl. IX. Figs. 4, 5, 6), which were not capable of being protruded in those families and genera in which they were folded back upon themselves, and supported by a calcareous skeleton. In *Rhynchonella,* where the elongated spiral arms are only slightly supported at their origin by two short projecting calcareous processes, they could be unrolled at the will of the animal and protruded to some distance beyond the margins of the valves. When forcibly stretched out, they are said to be more than four times the length of the shell, and to support some 3000 cirri (Pl. IX. Fig. 8). It must, however, remain for ever uncertain whether in the extinct genera *Spirifera*, *Atrypa*, and others, in which the spirally coiled fleshy arms were supported throughout their entire length by a calcified skeleton, the animal could protrude its labial appendages beyond the margin of the valves.

In some families—*Rhynchonellidæ*, *Productidæ*, and others—these organs are spiral and separate; in others, *Lingulidæ*, only at their extremities. It is almost certain that these beautiful organs, by means of their cirri and the cilia they are doubtless furnished with, are not only instrumental in carrying floating nutrimental particles or minute microscopic organisms to the mouth (which is situated between the appendages at their origin), but are subservient to the function of respiration. Hancock observes that "to prove that the brachial organs subserve the function of gills, as well as that of sustentation, it is only necessary to refer to the manner in which the blood circles round the arms (labial appendages), and is carried to the cirri; but more particularly to its circulating through these latter organs, returning direct from them to the heart."

(*To be continued in our next Number.*)

FIG.

EXPLANATION OF PLATE VII.

1. *Terebratula septentrionalis.* A cluster of eggs from the genital band (magnified).
2. ——— Egg from the perivisceral chamber, immediately after their escape from the pallial sinuses.
3. ——— Egg; first ciliated stage.
4, 5. ——— Transverse division of embryo, showing long tuft of cilia at cephalic extremity.
6, 7, 8. ——— Embryo, showing various outlines assumed in, while swimming.
9, 10. ——— Embryos attaching themselves by their caudal segment.
11. ——— Embryo showing first appearance of caudal or peduncular segment.
12, 13, 14. ——— Successive changes of the embryo, showing formation of dorsal and ventral areas by the folding and growth of the thoracic ring.
15, 16. ——— Embryo, the deciduous setæ appear in this stage.
17. ——— Free swimming embryo.
18. ——— First stage, in which the mouth makes its appearance, and dorsal and ventral plates become distinctly marked.
19. ——— Earliest stage, showing arrangement of deciduous setæ, and contour of embryonic shell.
20. ——— A considerably advanced stage, showing subsequent widening of the anterior portion of the dorsal and ventral plates.

All the above enlaged figures are taken from Prof. Morse's memoir on the embryology of *Terebratulina*.

21. *Waldheimia cranium.* Showing the manner in which it attaches itself by the means of its peduncle. *a*. ventral; *b*. dorsal valve; *p*. peduncle.
22. *Discina lamellosa.* Showing the manner in which it attaches itself and forms clusters of large dimensions. Upwards of one hundred specimens thus attached were sent to me by Prof. Verrill, from Callao, Peru. *p*. peduncle.
23. *Crania ignabergensis* (fossil). Showing the manner in which it attaches itself to submarine rocks and corals by a portion of the surface of one of its valves.
24. *Chonetes striatella* (fossil). To show the row of hollow spines that rise from the upper edge of the area of the dorsal valve.
25. *Terebratula sphæroidalis* (fossil). Longitudinal section to show the loop and large free space for the occupation of the animal. *a*. ventral; *b*. dorsal valve.

26. *Davidsonia Verneuilii* (fossil). To show the great thickness of the ventral valve *a*, and its mode of attachment to submarine objects by a portion of the substance of this valve. *b.* dorsal valve; *d.* small free space left for the animal.
27. *Productus Llangollensis* (fossil). Longitudinal section to show the great difference in thickness of the valves. *a.* ventral; *b.* dorsal; *d.* space left for animal.
28. *Strophomena filosa* (fossil). To show the small space left for the animal between the valves.
29. *Waldheimia flavescens.* Enlarged section of shell (after King). *o.* thick calcareous innermost division; *n.* intermediate thin calcareous division; *m.* outer division of thin membrane; *e. f.* canals traversing the calcareous layers *o* and *n*; the lower half of the perforation being considerably smaller in diameter than the upper one.
30. *Terebratula bullata* (fossil). Section of shell near the external surface and parallel to it, showing the remarkably large size and close proximity of the perforations. 100 diameters.
31. *Waldheimia flavescens* or *australis.* Internal surface of the shell, showing the imbricated arrangement of the extremities of the prisms, which are seen longitudinally at *b*, magnified 100 diameters.
32. ——— Vertical section, considerably enlarged, so as to show the ordinary trumpet-like form of the vertical passages and remarkable condition which they exhibit in the inner and (probably) later-formed layer.
33. *Rhynchonella psittacea.* Portion of the internal surface of the shell more highly magnified, showing the imbricated arrangement and the entire absence of perforations, magnified 100 diameters.
34. ——— Portion of the shell, showing at *a* the internal surface, with the imbricated arrangement of the extremities of its component prisms, and at *b* the aspect of the prismatic substance as displayed by a fracture nearly in the direction of the length of the prisms, showing also entire absence of the least trace of perforations. Magnified 40 diameters. Figs. 30 to 34 after Dr. Carpenter.
35. *Lingula anatina.* Longitudinal section of the shell to show the alternation of calcareous and horny layers; *b. b.* calcareous layers perforated by minute canals; *d. d.* horny layers. After Dr. Gratiolet.
36. *Crania anomala* (enlarged). Interior of the dorsal valve to show the position of the spiral appendages. From a specimen in the Museum of the School of Mines.

FIG.

CLISTENTERATA. PLATE VIII.

1. *Terebratula carnea* (fossil). Interior of the dorsal valve, to show the short simple loop.
2. *Terebratulina caput-serpentis.* Interior of the dorsal valve, to show the ring-shaped loop.
3. *Magas pumilus* (fossil). Longitudinal section to show the large central septum and disunited deflected portion of the loop.
4. *Bouchardia tulipa.* Interior of the dorsal valve, to show the anchor-shaped apophysis.
5. *Thecidium mediterraneum.* Seen in profile. The valves opened as in life. After Lacaze-Duthiers.
6. *Spirifer Schrenkii* (fossil). Interior of the dorsal valve, showing the cardinal process, quadruple impression of the adductor muscle, and one of the calcareous spiral laminæ for the support of the labial appendages.
7. *Atrypa reticularis* (fossil). Interior of the dorsal valve, showing the position and shape of the spiral laminæ for the support of the labial appendages.
8. One of the spiculæ of the mantle of *Terebratulina caput-serpentis* highly mag.
9. *Rhynchonella psittacea* (after Hancock) much enlarged. Dorsal view of the animal; *a.* pallial lobe; *c.* peduncle; *d.* great pallial sinuses giving off branches at the margin; *i.* extremities of adductor muscle; *n.* liver; *x.* spiral brachial apparatus; *z.* genitalia and muscular ties uniting the walls of the genital sinuses.
10. *Waldheimia australis* (after Hancock). Diagram of longitudinal section of marginal portion of valves in connexion with the mantle, much magnified;

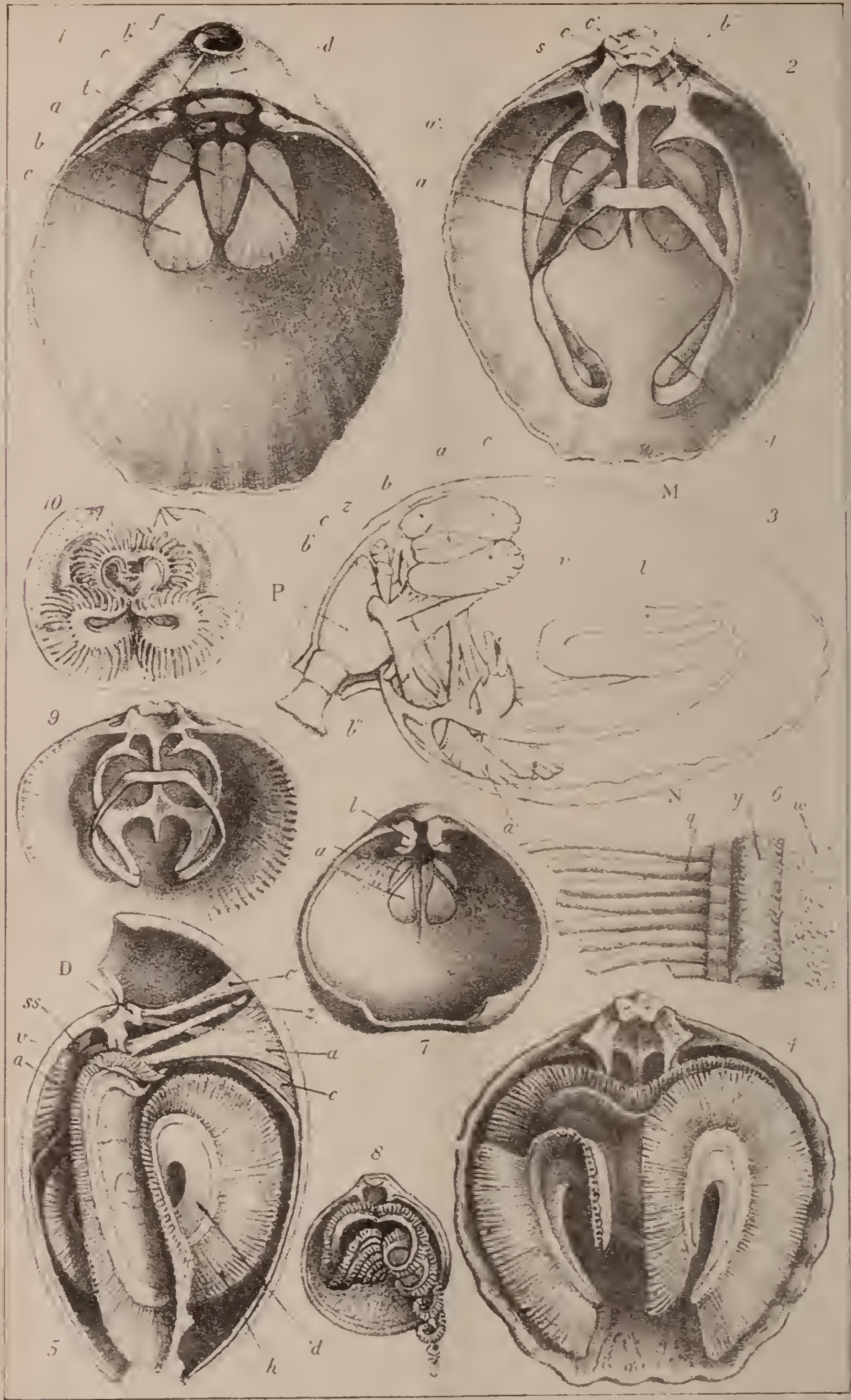
a. margin of valve; *b.* shell exhibiting prismatic structure; *c. c.* pallial cæca penetrating ditto; *d.* great pallial sinus; *e.* marginal vessels; *f.* outer lamina of mantle; *g.* external reticulated layer of ditto, in which the pallial cæca take their origin; *h.* homogeneous layer of other lamina; *i.* inner lamina of mantle; *j.* epithelium; *k. k.* membrane lining pallial sinus; *n.* inner ditto; *o.* marginal fold; *p.* one of the setæ; *q.* follicle of ditto; *r.* prolongation of glandular matter of follicle; *s.* marginal muscles; *t.* extreme pallial margin.

(*Plates* IX. *and* X. *will appear in our next Number.*)

II.—THE MAGNESIAN LIMESTONE AND NEW RED SANDSTONE IN THE NEIGHBOURHOOD OF NOTTINGHAM.

By W. T. AVELINE, F.G.S.,
Of the Geological Survey of England and Wales.

SINCE the Government Geological Survey of the country around Nottingham was made in the year 1859, and the Explanation on the Geological Map Quarter-sheet 71 N.E. was written in 1861, papers by local geologists have been written, stating that in the neighbourhood of Nottingham a perfect conformity existed between the Magnesian Limestone and the New Red Sandstone. This being totally at variance with conclusions I came to when I surveyed that country, I have been for some time past desirous to say a word on the subject, but being deeply occupied with the old rocks of the Lake district, I have put it off from time to time. I felt little doubt in my mind, when surveying the neighbourhood of Nottingham, that there was a considerable break between the Magnesian Limestone and the New Red Sandstone, and this opinion was completely confirmed as I continued my survey northwards through Nottinghamshire into Yorkshire. Unfortunately I did not make a statement regarding this break between the two formations in my Explanation on Sheet 71 N.E. Wishing to compress my observations as much as possible to form a pamphlet, the price of which would not be more than six-pence, much that might have been of interest was left out. But in my Explanation on Geological Map Sheet 82 N.E., the country in the neighbourhood of Worksop, I have given my proofs of this great break. I have shown that in the district to the north of Worksop the Permian series consists of at least four divisions. To begin at the top, there are the Upper Marls; next below the Upper Magnesian Limestone so-called, though it contains little or no Carbonate of Magnesia; then the Middle Marls and Sandstones; and, lastly, the lowest and chief member of the Permian series, the Lower Magnesian Limestone. I state that the Bunter Sandstone overlaps the Upper Permian Marls throughout most part of the district, and before the neighbourhood of Worksop is reached the Upper Limestone is also overlapped. From Worksop southward to Nottingham there are only left the Middle Marls and Lower Magnesian Limestone. Between these two places the Middle Marls are frequently overlapped, and, finally, west of Nottingham, the Lower Magnesian Limestone is itself overlapped, the New Red Sandstone resting on the Coal-measures. Therefore, in the neighbourhood of Nottingham, instead of there being a perfect conformity between the Magnesian



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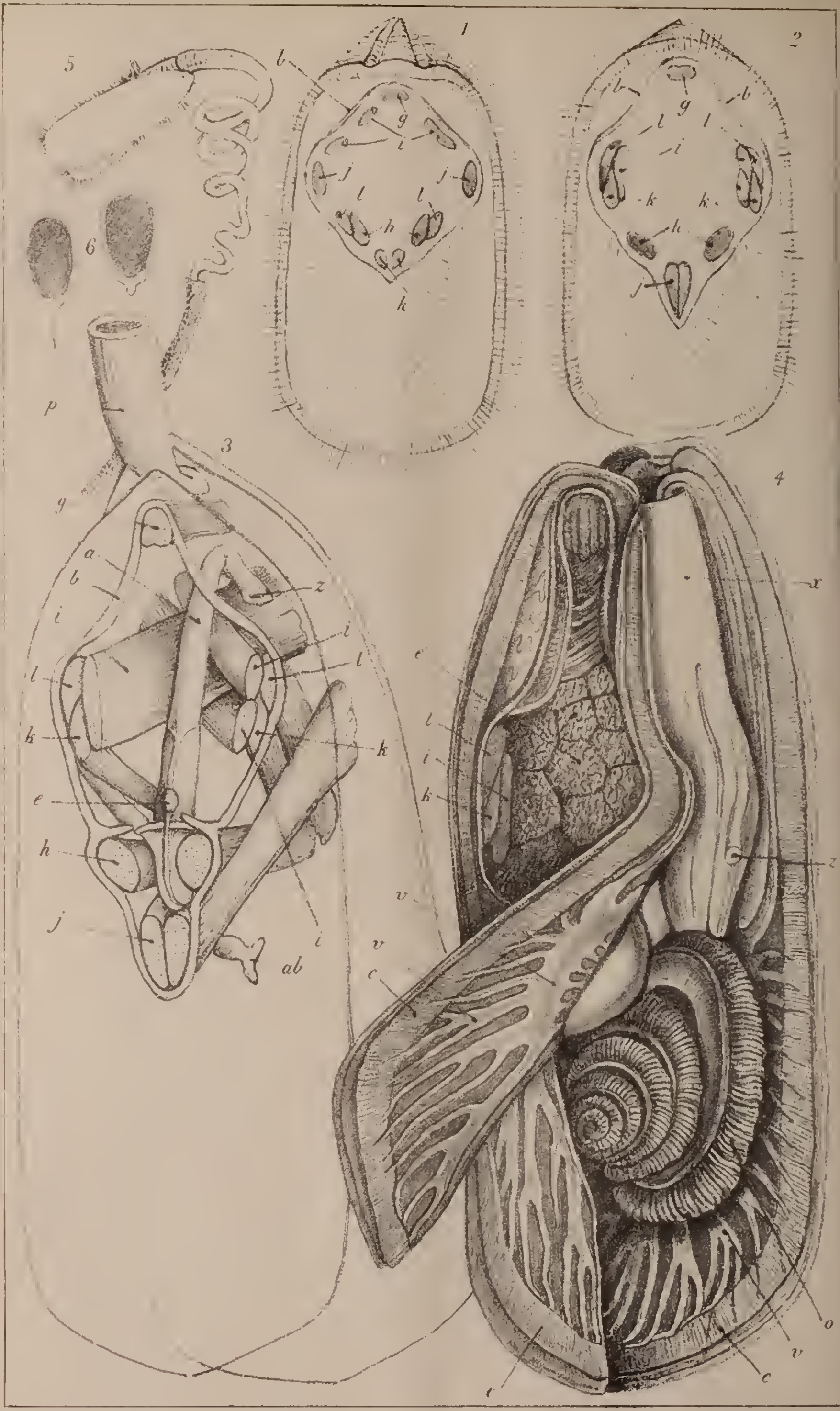

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TRETENTERATA

accomplished in about two hours, which was half the time it had taken us to ascend.

From the inhabitants we learnt that the mountain is regarded as being holy, and that at certain seasons they make solitary pilgrimages to its summit. We, however, had been the first to see the eruption.

Earthquakes, although so common on the mainland, are said not to occur here; and the only shocks that have been felt are those which were produced at the time of the breaking out of the volcano. This statement appeared to find some confirmation in the fact of a strong earthquake having occurred in Yokohama and Yeddo at the time of our making our inquiries, without being perceived by us. Several other localities in Japan are reported as being free from such annoyances; but how far these statements may be relied on needs investigation. Some of these districts are in the neighbourhood of recently active volcanos. If it is admitted that in the immediate vicinity of certain active volcanos, earthquakes are unknown, whilst in the surrounding districts they are strongly felt, the idea would at once suggest itself that round these particular volcanos, conditions exist which ward off the advance of any seismic wave. Thus, for example, a lake of lava beneath the unaffected area might accept a wave, but, for want of proper contact with the the rocks above, would be unable to transmit its effect in their direction. Owing to the state of the weather, and the short time we remained upon the island, conditions were very unfavourable for making accurate observations.

Next morning we set sail for home, a distance which in coming had been traversed in only six hours; but in returning, through the roughness of both wind and water, occupied two days.

II.—WHAT IS A BRACHIOPOD?

By THOMAS DAVIDSON, F.R.S., F.G.S., V.P.P.S.

PART II.

(PLATES IX. AND X.)

(*Continued from the April Number*, p. 155.)

Muscles.—As the number and position of these organs differ materially in the two great divisions into which the Brachiopoda have been separated, and to some extent, also, in the different genera of which each division is composed, it may be desirable to treat this subject under two different heads.[1]

In the *Clistenterata,* of which the genus *Terebratula* may be taken as an example, five or six pairs of muscles are stated by Hancock, Gratiolet, and others to be connected with the opening and closing of the valves, or with their attachment to, or movements upon the peduncle. First of all, the adductors or occlusors consist of two muscles, which, bifurcating near the centre of the shell cavity, produce a large quadruple impression on the internal surface of the small valve, and a single divided one towards the centre of the large or ventral valve. The function of this pair of muscles is the closing of the valves. Gratiolet, who has likewise described with great minuteness the muscles of the Brachiopoda, informs us that those which close and open the valves were the only ones known to Pallas, but that he clearly defined their positions and functions. The same was done by Blainville and Quenstedt, but the absence of good figures caused much uncertainty to prevail. This deficiency was subsequently supplied by Hancock's and Gratiolet's admirable illustrations.[1] Two other pairs have been termed *divaricators* by Hancock or *cardinal muscles* (= muscles diducteurs of Gratiolet), and have for function the opening of the valves. The divaricators proper are stated by Hancock to arise from the ventral valve, one on each side, a little in advance of, and close to the adductors, and, after rapidly diminishing in size, become attached to the cardinal process, a space or prominence between the sockets in the dorsal valve. The *accessory divaricators* are, according to the same authority, a pair of small muscles which have their ends attached to the ventral valve, one on each side of the median line, a little behind the united basis of the adductors and again to the extreme point of the cardinal process. Two pairs of muscles, apparently connected with the peduncle and its limited movements, have been minutely described by Hancock as having one of their extremities attached to this organ. The *dorsal adjustors* are attached to the ventral surface of the peduncle, and are again inserted into the hinge-plate in the smaller valve. The *ventral adjustors* are considered to pass from the inner extremity of the peduncle, and to become attached by one pair of their extremities to the ventral valve, one on each side of, and a little behind, the expanded base of the divaricators. The function of these muscles, according to the same authority, is not only that of erecting the shell, but also that of attaching the peduncle to the shell, and thus to effect the steadying of it upon the peduncle.

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[1] Unfortunately almost every anatomist who has written on the muscles of the Brachiopoda has proposed different names for each muscle; hence much confusion has arisen which can but be regretted.

Gratiolet describes the peduncle with great care, and states that it is composed of two portions:—1. A horny sheath formed of concentric epidermic layers, very analogous to that which Prof. Vogt described in *Lingula*. 2. A fibrous stem enveloped by the sheath. This stem, formed of tendinous fibres, is fixed by its free extremity to different marine objects; the other end passes through the foramen into the shell, and ends in a bulbous-shaped extremity.

Such is the general arrangement of the shell muscles in the division composing the articulate Brachiopoda, making allowance for certain unimportant modifications observable in the shells composing the different families and genera thereof.

In the *Tretenterata*, of which *Lingula* may be cited as an example, the myology is much more complicated, and anatomists have differed considerably in their respective views concerning the function of some of the muscles. They have been described by Vogt, Hancock, Gratiolet, and others, and more recently by King, whose views I shall adopt, as they seem to carry with them a greater degree of plausibility[1] (Pl. X. Figs. 1, 2). Of the shell or valvular muscles he makes out five pairs and an odd one, and individualises their respective functions as follows. Three pairs are *laterals*, having their members limited to the sides of the shell: one pair are *transmedians*, each member passing across the middle to the reverse side of the shell: while the odd muscle occupies the umbonal cavity. The central and *umbonal muscles* effect the direct opening and closing of the shell; the *laterals* enable the valves to move forward and backward on each other: and the *transmedians* allow the similar extremities (the rostral) of the valves to turn from each other, to the right or the left, on an axis subcentrically situated, that is, in the medio-transverse region of the dorsal valve. It was long a matter in discussion whether the animal could displace its valves sideways when about to open its shell; but this point has been set at rest by Professors Semper and Morse, who observed the animal perform the operation. They mention that it is never done suddenly, or by jerks: as the valves are at first always pushed to one side several times, and back again on each other, at the same time opening gradually in the transverse direction, till they rest opposite to one another and widely apart. Those who had not seen the animal in life, or who did not believe in the possibility of the valves crossing each other with a slight obliquity, would not consent to appropriating any of its muscles to that purpose, and consequently attributed to all the lateral muscles the simple function of keeping the valves in an opposite position, or holding them adjusted. We have not only the observations of Semper and Morse, but the anatomical investigations of King to confirm the sliding action or lateral divarication of the valves of *Lingula*.

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[1] Journal de Conchyliologie, Octobre, 1857.

In the *Clistenterata*, where no such sliding action of the valves was necessary, or possible, no muscles for such an object were required: consequently none took rise from the lateral portions of the valves, as in *Lingula*. In an extinct group, however, the *Trimerellidæ*, which seems to be somewhat intermediate in character between the *Tretenterata* and *Clistenterata*, certain scars have been found which appear to have been produced by rudimentary lateral muscles; but it is doubtful (considering the shells are furnished with teeth, though but rudely developed) that such muscles enabled the valves, as in *Lingula*, to move forward and backwards upon each other. There are muscles connected with other portions of the animal, such as the *parietal* so strongly defined in the *Tretenterata*, and distinctive peculiarities of the peduncle, etc.; but the limited space at my disposal will not admit of more than a passing allusion to them.[2]

Ranges of Depth.—All Brachiopoda are inhabitants of the sea. A vast amount of important and accurate information has been collected during the past ten years with respect to the geographical distribution of the recent species, as well as to the marine depths they inhabit or prefer.[1]

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[1] King, Annals and Mag. of Nat. Hist., 4th series, vol. xii., 1873.

[2] Davidson and King, on the *Trimerellidæ*, Quarterly Journal of the Geological Society, 1874, vol. xxx. p. 124.

This important knowledge is mainly due to the numerous well-conducted and equipped dredging expeditions carried on by private individuals, and by the Governments of the leading maritime States.

Previous to these investigations the data we possessed with respect to the habitat, and ranges of depth were, in most cases, vague and unsatisfactory. It has also been ascertained that the Brachiopoda are much localised, and usually occur in great numbers in their favourite haunts.

We can know nothing with certainty in respect to the ranges of depth at which the extinct species lived; but some idea as to their probable depths can be surmised from a study of recent forms.

As far as our present information will carry us, the *Tretenterata* (*Lingula*, etc.) do not appear to have been found at a greater depth than from 1366 to 2000 fathoms.

Lingula abounds in particular haunts, and lives at about half tide-mark, and partly buried in mud; or at depths varying from three or four inches from the surface of the sea to seventeen fathoms. Prof. Morse describes a species which he found in vast numbers in a sand-shoal at low-water: the peduncle, six times the length of the shell, was partly encased in a sand tube (Pl. X. Fig. 5). He observed likewise that this species (*Lingula pyramidata*) had the power of moving over the sand by the sliding motion of the two valves, using at the same time the fringes of setæ, which swing promptly back and forth like a galley of oars, leaving a peculiar tract in the sand. In the motion of the setæ he noticed the impulse commencing from behind, and running forward.

Discina has been found attached to stones at low-water mark, and has been dredged from depths ranging from five to nearly 2000 fathoms; very often clustered together in vast numbers, and adhering, in all stages of growth, by their peduncle to the surface of the shell of their neighbour, one above the other, till they formed a living mass of considerable breadth and thickness.

Crania is found in great numbers adhering to stones and shells at depths of from eighteen to 530 fathoms. Lucas Barrett informs us that the cirri are protruded, but not the brachial appendages, beyond the margin of the shell, and that the valve opens by moving upon the straight side of the hinge without sliding the valve.

The genera and species of *Clistenterata* lived at depths ranging from about half tide-mark to 2600 fathoms. At that great depth, between Kerguelen Island and Melbourne, the "Challenger" Expedition brought up, among other things, "a very elegant little Brachiopod;" another species was dredged by the same expedition three hundred miles east of St. Paul's Rocks, Atlantic, at a depth of 1850 fathoms, but the larger number of species live at depths of from five to three, or four hundred fathoms, usually attached by their peduncle to various marine objects, and very often to the outer surface of one another's valves, and even quite young individuals to the peduncle of the parent shell, as may be seen in a number of specimens of *Terebratulina septentrionalis* sent me from America by Prof. Verrill. I have likewise clusters of *Terebratella rubicunda* from New Zealand, adhering to each other in a similar manner. They occur also in great numbers attached by a shorter or longer peduncle to coral reefs, and several minute species were found by Dr. Gwyn Jeffreys fixed to sea-weeds. *Kraussina rubra*, from the coast of Natal in South Africa, was described by Dr. Gray as found attached in vast numbers to *Ascidia* and stems of sea-weeds. We may likewise mention that a small species of *Kraussina* has been recently obtained by Mr. Vélain (during the French expedition to make observations relative to the transit of Venus) in the interior of the breached and submerged crater-basin of the Island of St. Paul, attached, in vast numbers, to rocks at low tide-mark,[1] and I am informed by Dr. Gwyn Jeffreys that *Terebratulina caput-serpentis* was found by the late Mr. R. T. Loweliviry, nearly forty years ago, in the living state, attached to a rock at low-water mark, on a part of the Scottish coast where the tide falls only a few feet. The same species occurs also at variable depths, having been dredged alive from depths varying from three to upwards of 150 fathoms. *Waldheimia cranium* has been obtained from depths varying from 160 to 228 fathoms. Dr. Gwyn Jeffreys does not believe that the habitat of any invertebrate animal is affected by bathymetrical conditions. The late Prof. J. Beete Jukes collected any number of *Waldheimia flavescens* or *australis* while boating in Australia among the reefs; they were merely washed by the tide, and he gathered them with his hand like limpets on the shore.

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[1] The reader is referred to an important paper upon this subject by Prof. Edward Suess, über die Wohnsitze der Brachiopoden (Aus dem xxxvii. und xxxix. Bande, Wien, 1859, 1860, Akademie der Wissenschaften besonders abgedruckt).

Lucas Barrett informs us that this species, as well as *Terebratulina caput-serpentis*, manifested a remarkable power and disposition to move on its peduncle, and that the cirri were almost constantly in motion, and he often observed them to convey small particles to the channel at their base. Dr. J. Gwyn Jeffreys, who has watched *Terebratulæ* alive, informs us that they were incessantly opening and folding their brachial or labial appendages, and drawing and sucking in by means of the whirlpool thus caused every animalcule within their influence.

Classification.—Having briefly alluded to some of the most important characters of the shell and animal of the Brachiopod, it is necessary to refer to their classification. This matter will be found fully discussed up to the year 1853 in the general introduction to my monograph on "British Fossil Brachiopoda."[1] I then published my views, which were subsequently very generally adopted both by British and foreign palæontologists; but I did not omit to impress upon my readers that we were not then (neither are we now) in a condition to prepare a complete or satisfactory classification of the numerous species composing the class. In 1853 I divided the Brachiopoda into eight families comprising twenty-four genera and twenty-two sub-genera; but, during the years that have elapsed since that date to the present time, about seventy more genera or sub-genera have been described. I published a list of them in the *Sussex Daily News* for the 20th of August, 1872, and they will be found recorded in the table accompanying this memoir, where their geological distribution in time has been tabulated, as far as the present state of our information will permit. It it, however, very probable that a certain number of the names there recorded will have to be placed amongst the synonyms, and it is of the utmost importance that genera should not be founded on trifling modifications, or unimportant details which exist only in some abnormal forms. In 1855,[2] I proposed certain modifications in the arrangement published in 1853 by getting rid of the sub-families. Much consideration on my part has been devoted to the subject; but I feel that in order to place the known genera and species in their respective families, or into new ones that will have to be created, much more information must be acquired. The subject is immense when one has to grapple with between 5000 and 6000 described species, varieties or synonyms; and it must likewise be remembered that many of the extinct genera have as yet been but imperfectly elaborated. The material in hand is, however, so great that doubtless, in time, palæontologists will be able to lay before the public a complete history of a class, which, as will be shortly shown, has played an important part in the great life-system of our globe, from its dawn to the present time. It will be necessary, I think, as has already been stated, to admit the two great divisions, *Tretenterata* and *Clistenterata*, into any scheme of classification, although it is impossible to say whether all the extinct genera were provided with an anal aperture, or otherwise.

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[1] Mr. Vélain informs me, that the Brachiopods he forwarded to me (a species of *Kraussina*) are found in great abundance on the shore, in the interior crater of the island of St. Paul. During the ordinary low tides they are scarcely covered by water, and are alternately covered and left bare at the ebb and flow of the tide, but twice a month, during the high tides, they are left completely dry. They occur only in an area of a few yards, and consequently at a very shallow depth, doubtless because they find there those undisturbed conditions to which they are accustomed in other localities.

The TRETENTERATA would comprise the families *Lingulidæ*, *Discinidæ*, *Craniadæ*, and perhaps one or two others.

The CLISTENTERATA would include the families *Terebratulidæ*, *Thecidædæ*, *Spiriferidæ*, *Rhynchonellidæ*, *Pentameridæ*, *Orthidæ*, *Strophomenidæ*, *Productidæ*, and perhaps two or three others that will have to be characterized. By far the larger number of described genera and species would find their places in this last great division and the above-named families. We will now, very briefly, notice some of the characters of the families above indicated.

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[1] A French revised translation of my general introduction by MM. Deslongchamps, father and son, will be found published in vol. x. of the Mémoires de la Société Linnéenne de Normandie, 1856.—A German translation by Prof. E. Suess and Count Marschall was also published in Vienna in the same year, 1856.

[2] Annals and Mag. of Nat. Hist. 2nd ser. vol. xvi.

TRETENTERATA, King.

Family 1. *Lingulidæ.*—Shells generally either oblong or circular, with a peduncle, sometimes of considerable length, passing out between the valves or through a narrow channel in the hinge-margin; texture horny and calcareous: no calcified support for the labial appendages, the fleshy spiral coils directed upwards. This family would comprise the following genera: *Lingula. Lingulella, Lingulops, Lingulepis, Glottidia, Monobolina, Obolus, Obolella, Dignomia, Schmidtia, Acrites, Volborthia,* and some others. It may, however, be hereafter desirable to group the genera above recorded into two groups or families, *Lingulidæ* and *Obolidæ. Lingulella* is one of the oldest, if not the oldest type of animal life now known, while *Lingula* appeared for the first time about the middle of the Cambrian period, and has continued to be represented up to the present time.

Family 2. *Discinidæ.*—Shells more or less circular or oval-shaped, attached by a peduncle passing through a foramen in the ventral valve; shell calcareous and horny, setæ extremely long, barbed with cilia of great length: labial appendages fleshy, curved backwards, with small terminal spire directed downwards, as in *Crania*. Genera: *Discina, Tremates, Discinisca, Kutorgina* (?), *Acrotreta* (?), *Siphonotreta* (?). *Discina* appeared about the middle of the Cambrian period, and has continued to exist up to the present time.

Family 3. *Craniadæ.*—Shells orbicular or limpet-like, entirely free or attached by a greater or lesser extent of the under surface of their ventral valve: labial appendages spirally coiled, directed towards the bottom of the dorsal valve: shell calcareous, perforated by minute canals. Genera: *Crania, Craniops, Craniscus, Pholidops.* The genus *Crania* appeared for the first time during the Silurian period, and has continued to be represented up to the present time.

Family 4. *Trimerellidæ.* — Shells transversely or longitudinally oval: ventral valve usually the largest and flattest, with a more or less developed beak and area: ventral valves generally the most convex, hinge rudely or faintly dentated: all the genera are provided with a solid or vaulted muscular platform in the interior of both valves; no calcareous support for the labial appendages: shell calcareous, and in two of the genera very massive. All the forms are extinct. Genera: *Trimerella, Monomerella, Dinobolus.* The genera and species of this family are restricted to the Silurian period.

CLISTENTERATA, King.

Family 5. *Terebratulidæ.*—Shells very variable in shape, with a prominent beak, truncated by a circular foramen, partly completed by a deltidium in one or two pieces; labial appendages united to each other by a membrane, variously folded upon themselves, and in some genera spiral at their extremities. These appendages are entirely or partially supported by a calcified process assuming a great variety of shapes. All the species lived attached to submarine bodies by the means of a peduncle. Shell structure perforated by canals. Genera: *Terebratula, Terebratulina, Waldheimia, Terebratella,* *Megerlia, Kraussina, Terebrirostra, Magas, Mannia, Bouchardia, Platidia, Argiope. Cistella, Zellania, Reusselaria, Gwynia, Macandrevia Diclasma, Megantheris, Stringocephalus, Trepidolopsis* and some others. *Terebratula* appeared at the close of the Silurian period, and continued to be represented up to the present time; but the larger number of genera have had a very limited distribution in time.

Family 6. *Thecidadæ.* — Shells small, thick, varied in shape, attached by a larger or smaller portion of the shell substance of their ventral valve; area flat; deltidium indistinct; valves articulated; loop in the dorsal valve folded into two or more lobes lying in hollows of corresponding shape excavated in the substance of the valve. This loop, or apophysary ridge, supports the brachial membrane, whose thickened and cirrated margin is apparently attached to the inner sides of the grooves; shell structure perforated by canals. Only one genus at present known, *Thecidium.* It appeared in the Trias, and has continued to be represented up to the present time.

Family 7. *Spiriferidæ.*—Shells variable in shape, ovate, elongated, transverse, trilobate, etc., with the hinge-line straight and extended into wing-shaped expansions: valves articulated, with or without a flattened area in the ventral valve: animal free, or attached during at least a portion of its existence by means of a peduncle, or by muscular fibres issuing from an angular or circular foramen in the beak or area of the ventral valve. Dorsal valve internally furnished with two calcareous spiral processes connected in different manners and directed outwards towards the side of the shell; these processes afforded support to the brachial appendages. This family comprises the following impunctate and punctate genera: *Spirifera, Cyrtia, Cyrtina, Spiriferina, Martinia, Athyris, Meristina, Merista, Retzia, Nucleospira, Trematospira, Rhynchospira, Meristella, Zygospira, Coclospira, Rhynchotrema, Uncites, Ambocœlia, Charionella, Syringothyris, Eumetria, Suessia, Vetulina* (?). The first species belonging to this family made its appearance during the Silurian period, and the family became entirely extinct in the Inferior Oolite.

Family 8. *Rhynchonellidæ.* — Valves articulated, very variable in shape, more or less trigonal, often trilobed or ovate, smooth or plicated; foramen beneath a usually produced and pointed beak, completed by a deltidium at times concealed: brachial appendages fleshy and spirally coiled, flexible, and supported only at their origin by a pair of short-curved shelly processes, or throughout by two broad spirally-coiled lamellæ (these spires are vertical, closely adpressed, and directed upwards towards the centre of the valve): shell structure fibrous and impunctate. This family comprises the following genera: *Rhynchonella, Atrypa, Eatonia, Leptocœlia, Brachymerus, Anastrophia, Leiorhynchus, Camarophoria, Rhynchopora, Rhynchonellina,* and one or two others. The first species appeared during the Silurian period, and representatives of the family have continued to the present time.

Family 9. *Pentameridæ.* — Shells ovate, somewhat pentagonal; valves articulated, without hinge-area; foramen angular; no deltidium: inside of ventral valve two contiguous vertical septa of greater or lesser length, which coalesce into one median plate, and then diverge to form the dental plates, inclosing a triangular trough-like chamber. In the interior of the dorsal valve are two longitudinal septa of variable dimensions, to which the socket-walls converge, and to which they are joined, forming two more or less developed and inclined plates, to the produced extremities of which were no doubt affixed the fleshy spiral labial appendages. Shell structure impunctate. Genera: *Pentamerus*, *Pentamerella*, and perhaps one or two others.

Family 10. *Strophomenidæ.* — Shells semicircular, transverse, or elongated: valves usually concavo-convex, regularly arched, geniculated or depressed, so that the valve, which is convex in some species, is concave in others, and *vice versâ;* hinge-line long, straight: area in ventral valve flat, with a fissure partly arched over by a pseudo-deltidium. Valves sometimes uniformly convex, the dorsal one sometimes depressed with an area divided by a triangular foramen. In the interior of the dorsal valve a small simple projecting cardinal process is situated between prominent socket-walls, to the inner extremities of which were (probably) attached the brachial appendages. Genera: *Strophomena Streptorhynchus*, *Strophodonta*, *Leptæna*, *Orthis*, *Orthesina*, *Skenidium*, *Brachyprion*, *Discœlosia*, *Meekella*, *Davidsonia* (?), and several others. The first species appeared during the Silurian period, and the last in the Upper Lias. It may, however, be necessary to group the genera provisionally placed in *Strophomenidæ* into one or two families or sub-families. A great family *Orthidæ* might be established. *Strophomena* differs from *Orthis* in having a closed fissure, and the cardinal process bifid or trilobed, while in *Orthis* it is generally formed of one piece. In *Strophomena* it is situated directly between the dental sockets, or has between them and it a small prominent ridge, or brachial process; for this last is scarcely developed, where it exists, and forms a marked contrast to what we find in same valve of *Orthis*. There are also four more or less distinctly defined adductor depressions, which are longitudinally parallel to each other, and separated by ridges, while in *Orthis* these four divisions are placed in pairs one above the other.

Family 11. *Productidæ.* — Shells more or less concavo-convex, oval, semi-oval, or angular, and generally auriculated; the hinge-line straight, with or without teeth and sockets for the articulation of the valves. Surface of ventral valve or hinge-line more or less furnished with tubular spines, sometimes of considerable length: no calcareous process for the support of the brachial appendages: shell structure perforated by canals: cardinal process prominent, trilobed or bilobed. Under this a narrow longitudinal ridge generally extends to about half (or more) of the length of the valve, and on each side are seen the ramified dendritic impressions, which may be attributable to the adductor muscle. Outside, and in front of these are the two reniform impressions so characteristic of the family. Genera: *Productus*, *Strophalosia*, *Aulosteges*, *Chonetes*, *Productella*. The *Productidæ* made their first appearance during the Silurian time, and became extinct at the close of the Palæozoic period.

(*To be concluded in our next Number.*)

(Plates VII. and VIII. accompanied Part I. of Mr. Davidson's memoir.)

Fig. CLISTENTERATA. PLATE IX.

1. *Waldheimia flavescens.* Interior of ventral valve. *f.* foramen; *d.* deltidium; *t.* teeth; *a.* adductor muscular impressions (= occlusor *Hancock*) *close valves; c.* divaricator *Hancock* (= cardinal muscles *King* = muscles diducteur principaux, *Gratiolet*) *open valves*; *c′.* accessory divaricators *Hancock* (= muscles diducteurs accessoires *Gratiolet*); *b.* ventral adjustors *Hancock* (= ventral peduncular muscles or muscles du pedoncule paire superieur, *Gratiolet*); *b′.* peduncular muscle *Hancock.*
2. ——— Interior of dorsal valve. *c, c′.* Cardinal process; *b′.* hinge-plate; *s.* dental sockets; *l.* loop; *a.* adductor (=anterior occlusor *Hancock*; valvular muscles *King; a.* adductor (= posterior occlusor *Hancock*); *c′.* accessory divaricator, point of attachment (= muscles diducteurs accessoires Gratiolet; *b″.* dorsal adjustor, points of attachment (= dorsal peduncle muscle = muscles du pedoncule, paire inferieur *Gratiolet.*
3. ——— Diagram showing the muscular system after Hancock. M. ventral valve; N. dorsal valve; *l.* loop; *v.* mouth; *z.* extremity of intestine; *a.* adductor; *c.* divaricators; *c′.* accessory divaricators; *b.* ventral adjustors; *b′.* peduncular muscle; *b″.* dorsal adjustors; P. peduncle.
4. ——— Interior of dorsal valve to show the position of the labial or brachial appendages; a portion of the fringe of the cirri has been removed to show the brachial membrane and a portion of the spiral extremities of brachial appendages.
5. ——— Longitudinal section of valves, with a portion of the animal. *d, h.* labial appendages; *a.* adductor; *c′, c′.* divaricator muscles; D. cardinal process; *s, s.* septum; V. mouth. The adjustor or peduncular muscles have been purposely omitted.
6. *Waldheimia flavescens.* Portion of the labial appendages, enlarged, showing the interbranchial membrane. *w.* the canal; *y, q.* ciliated cirri coated with spiculæ (after E. Deslongchamps).
7. *Rhynchonella psittacea.* Interior of dorsal valve. *a.* adductor muscular impressions; *l.* short curved lamellæ for support of labial appendages.
8. ——— Showing the spirally rolled labial appendages (after Owen's original figure, Trans. Zool. Soc. vol. i. pl. 22, fig. 14); but I have given a more correct illustration of the position of the brachial appendages, of *R. nigricans*, in the Memoirs of the Soc. Linnéenne de Normandie, pl. x fig. 11, 1857.
9. *Terebratella Magellanica.* Interior of dorsal valves, to show the double attachment of the loop.
10. *Platidia anomioides.* Interior of dorsal valve, to show the position and shape of the brachial appendages.

TRETENTERATA. PLATE X.

1. *Lingula anatina.* Interior of ventral valve (diagram after King).
2. ——— Interior of dorsal valve. *g.* umbonal muscular impressions (*open valves*); *h.* central muscles (*close valves*); *i.* transmedial or sliding muscles; *b.* parietal band; *j, k, l.* lateral muscles (*j.* anteriors, *k.* middles, *l.* outsides), enable the valves to move forward and backward on each other.
3. ——— Diagram of the muscular system (after Hancock) The letters indicate the same muscles as are designated in King's figures 1 and 2; *p.* peduncle; *e.* heart; *a.* alimentary tube; *z.* anal aperture.
4. ——— enlarged (after Hancock), to show the dorsal pallial lobe or mantle turned back to expose the pallial chamber; *c.* marginal fold; *v.* pallial sinuses; *o.* spirally coiled brachial apparatus; *e″.* liver; *l.* lateral muscles; *k.* lateral muscles (middles); *i.* transmedial or sliding muscles; *x.* lateral wall of body; *z.* anal nipple.
5. *Lingula pyramidata* (after Morse). Showing manner in which the valves slide their valves, also portion of the long peduncle, to which sand has agglutinated in the shape of a tube.
6. Embryos removed from the pallial sinus of *Lingula anatina,* magnified 120 diameters, (after Owen).

a rising area, than by glaciers. (See GEOL. MAG., Decade II. Vol. III. Nos. 7, 8, 9, July, August, and September, 1876.)

Conclusion.—In conclusion I may say that it appears that the rocks of Newfoundland are exclusively old ones, a character which might be inferred from their metamorphosed and generally broken up and contorted appearances. Here and there fossils exist, but they are scarce. In all formations up to the Devonian and Carboniferous, which are the youngest excepting the general superficial covering of Drift, igneous rocks are abundant. During Silurian times there were probably large volcanos, which gave vent to fields of lava, and deposited large beds of ashes. But even these rocks also have undergone great changes, and are now only to be recognized as chloritic and serpentinous masses—a character of metamorphism which seems to be common to many of the formations. An important point about the serpentinous rocks is that they have been already proved to be the receptacles of mineral wealth. In many parts of the country there is the strongest evidence to show that the island has lately emerged from the sea, and during this elevation, for reasons which have in part been previously expressed, we believe that Coast-ice was the chief agent in impressing on the country the glaciated character which it now carries—a view which has subsequently been strengthened by observations on the coast of Finland. Besides the metalliferous wealth of the island, which is in the main confined to the serpentines of the Middle Quebec Group, much may be expected from the Coal-measures. When the value of these two formations becomes fully recognized, we may expect to see the local government stimulated to giving further aid to geological exploration,—explorers will be attracted, the dreary wastes of the almost unknown interior will be penetrated, and something more certain will be learnt about the early history and formation of our long-neglected and oldest colony NEWFOUNDLAND.[1]

III.—WHAT IS A BRACHIOPOD?[2]

By THOMAS DAVIDSON, F.R.S., F.G.S., V.P.P.S.

PART III.

(*With a large folding Table.*)

AFFINITIES OF THE BRACHIOPODA.

For some years past, the serious attention of several eminent malacologists has been directed to the endeavour to determine the

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[1] I refrain from more at present, than to make a few general remarks upon Mr. Milne's conclusions in regard to glacial action, and the rise of the land, as I shall probably have something to say upon these subjects at a future time. I think, however, there are evidences to show that there must have been enormous glacial action, probably intermittent; and that the rock-basins of many of the great lakes of the interior, and other phenomena at high elevations in the interior and on the coast, can only be accounted for as the result of such an agency. I also think that the evidences we have, of the rise of the land in *very* recent times, do not show an elevation of over a hundred feet *at most* over the present level of the sea.

My new Geological Map of Newfoundland will probably aid in illustrating both Mr. Milne's and my own remarks. It may be obtained at Mr. Edward Stanford's, 55. Charing Cross.—ALEX. MURRAY.

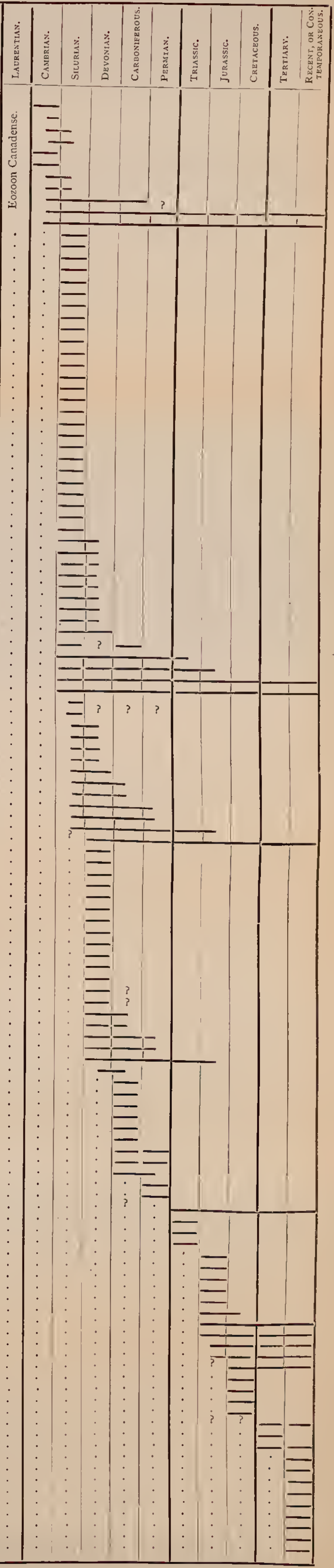
[2] (*Concluded from the May Number*, p. 208.)

TABLE INDICATING THE GEOLOGICAL DISTRIBUTION OF THE BRACHIOPODA IN TIME.

By Thomas Davidson, F.R.S., F.G.S., V. P. Pal. Soc., etc.

Geol. Mag. 1877. Decade II. Vol. IV.

Numbers.	GENERA.	AUTHORS.	DATE.	FAMILIES.
1	*Lingulella*	Salter	1861	*Lingulidæ*
2	*Lingulepis*	Hall	1863	*id.*
3	*Monobolina*	Salter	1857	*id.*
4	*Acrotreta*	Kutorga	1828	? *Discinidæ*
5	*Acrothele*	Linnarsson	1875	*Discinidæ*
6	*Iphidea*	id.	1875	?
7	*Kutorgina*	Billings	1861	?
8	*Obolella*	id.	1861	*Lingulidæ*
9	*Orthis*	Dalman	1827	*Strophomenidæ*
10	*Lingula*	Bruguière	1789	*Lingulidæ*
11	*Discina*	Lamarck	1819	*Discinidæ*
12	*Obolus*	Eichwald	1829	*Lingulidæ*
13	*Siphonotreta*	De Verneuil	1845	? *Discinidæ*
14	*Trematis*	Sharpe	1847	*Discinidæ*
15	*Porambonites*	Pander	1830	*Strophomenidæ*
16	*Eatonia*	Hall	1857	*Rhynchonellidæ*
17	*Triplesia*	id.	1859	?
18	*Cœlospira*	id.	1863	*Spiriferidæ*
19	*Lingulops*	id.	1871	*Lingulidæ*
20	*Dinobolus*	id.	1871	*Trimerellidæ*
21	*Rhynobolus*	id.	1871	*id.*
22	*Eichwaldia*	Billings	1858	?
23	*Stricklandinia*	id.	1859	*Rhynchonellidæ*
24	*Camerella*	id.	1859	?
25	*Trimerella*	id.	1862	*Trimerellidæ*
26	*Brachyprion*	Shaler	1862	*Strophomenidæ*
27	*Brachymerus*	id.	1865	*Rhynchonellidæ*
28	*Keiserlingia*	Pander	1860	?
29	*Helmersenia*	id.	1860	?
30	*Schmidtia*	Volborth	1868	? *Lingulidæ*
31	*Acritis*	id.	1868	?
32	*Volborthia*	Möller	1874	?
33	*Anastrophia*	Hall	1867	*Rhynchonellidæ*
34	*Meristina*	id.	1867	*Spiriferidæ*
35	*Rhynchotrema*	id.	?	*id.*
36	*Schizocrania*	id.	1875	*Discinidæ*
37	*Dicœlosia*	King	1850	*Strophomenidæ*
38	*Monomerella*	Billings	1871	*Trimerellidæ*
39	*Leptocœlia*	Hall	1857	*Rhynchonellidæ*
40	*Rensselæria*	id.	1856	*Terebratulidæ*
41	*Skenidium*	id.	1860	? *Strophomenidæ*
42	*Cryptonella*	id.	1861	?
43	*Meristella*	id.	1860	*Spiriferidæ*
44	*Zygospira*	id.	1862	*id.*
45	*Pholidops*	id.	1859	*Craniadæ*
46	*Cyrtia*	Dalman	1827	*Spiriferidæ*
47	*Dignomia*	Hall	1871	*Lingulidæ*
48	*Spirifer*	Sowerby	1815	*Spiriferidæ*
49	*Athyris*	McCoy	1844	*id.*
50	*Crania*	Retzius	1781	*Craniadæ*
51	*Rhynchonella*	Fischer	1809	*Rhynchonellidæ*
52	*Trematospira*	Hall	1857	*Spiriferidæ*
53	*Orthisina*	D'Orbigny	1849	*Strophomenidæ*
54	*Merista*	Suess	1851	*Spiriferidæ*
55	*Strophodonta*	Hall	1852	*Strophomenidæ*
56	*Nucleospira*	id.	1857	*Spiriferidæ*
57	*Rhynchospira*	id.	1857	*id.*
58	*Atrypa*	Dalman	1827	*id.*
59	*Pentamerus*	Sowerby	1813	*Rhynchonellidæ*
60	*Strophomena*	Rafinesque	1820?	*Strophomenidæ*
61	*Retzia*	King	1850	*Spiriferidæ*
62	*Chonetes*	Fischer	1837	*Productidæ*
63	*Leptæna*	Dalman	1827	*Strophomenidæ*
64	*Terebratula*	Llhwyd	1699	*Terebratulidæ*
65	*Megantheris*	Suess	1855	*id.*
66	*Stringocephalus*	Defrance	1828	*id.*
67	*Uncites*	id.	1828	*Spiriferidæ*
68	*Anaplotheca*	Sandberger	1855	?
69	*Davidsonia*	Bouchard	1849	?
70	*Vetulina*	Hall	1860	?
71	*Tropidolepis*	id.	1857	? *Terebratulidæ*
72	*Centronella*	Billings	1859	?
73	*Charionella*	id.	1861	*Spiriferidæ*
74	*Pentamerella*	Hall	1867	? *Rhynchonellidæ*
75	*Amphigena*	id.	1867	? *id.*
76	*Gypidula*	id.	1867	? *id.*
77	*Ambocœlia*	id.	1860	*Spiriferidæ*
78	*Leiorhynchus*	id.	1860	*Rhynchonellidæ*
79	*Productella*	id.	1864	*Productidæ*
80	*Cyrtina*	Davidson	1858	*Spiriferidæ*
81	*Productus*	Sowerby	1814	*Productidæ*
82	*Strophalosia*	King	1844	*id.*
83	*Spiriferina*	D'Orbigny	1847	*Spiriferidæ*
84	*Martinia*	McCoy	1844	*id.*
85	*Syntrielasma*	Meek	1866	?
86	*Syringothyris*	Winchell	1863	*Spiriferidæ*
87	*Meekella*	White	1867	*Strophomenidæ*
88	*Cryptacanthia*	id.	1867	?
89	*Aulacorhynchus*	Dittmar	1871	?
90	*Eumetria*	Hall	1863	*Spiriferidæ*
91	*Camarophoria*	King	1844	*Rhynchonellidæ*
92	*Streptorhynchus*	King	1850	*Strophomenidæ*
93	*Dielasma*	King	1859	*Terebratulidæ*
94	*Aulosteges*	Helmersen	1847	*Productidæ*
95	*Rhynchopora*	King	1862	? *Rhynchonellidæ*
96	*Thecidium*	Defrance	1828	*Thecididæ*
97	*Dimerella*	Zittel	1870	*Terebratulidæ*
98	*Amphiclina*	Laube	1865	?
99	*Koninckina*	Suess	1853	*Spiriferidæ*
100	*Craniscus*	Dall	1871	*Craniadæ*
101	*Hynniphora*	Suess	1855	?
102	*Zellania*	Moore	1854	*Terebratulidæ*
103	*Suessia*	Deslongchamps	1854	*Spiriferidæ*
104	*Rhynchonellina*	Gemellaro	1871	*Rhynchonellidæ*
105	*Ismenia*	King	1850	*Terebratulidæ*
106	*Waldheimia*	id.	1850	*id.*
107	*Terebratulina*	D'Orbigny	1847	*id.*
108	*Terebratella*	id.	1847	*id.*
109	*Argiope*	Deslongchamps	1842	*id.*
110	*Megerlia*	King	1850	*id.*
111	*Craniops*	Dall	1871	*Craniadæ*
112	*Kingina*	Davidson	1852	*Terebratulidæ*
113	*Terebrirostra*	D'Orbigny	1847	*id.*
114	*Magas*	Sowerby	1818	*id.*
115	*Cistella*	Gray	1853	*id.*
116	*Mannia*	Dewalque	1868	*id.*
117	*Laqueus*	Dall	1870	*Lingulidæ*
118	*Kraussina*	Davidson	1852	*Terebratulidæ*
119	*Bouchardia*	id.	1849	*id.*
120	*Platidia*	Costa	1852	*id.*
121	*Magasella*	Dall	1870	*id.*
122	*Discinisca*	id.	1871	*Discinidæ*
123	*Glottidia*	id.	1870	*Lingulidæ*
124	*Gwynia*	King	1859	*Terebratulidæ*
125	*Macandrevia*	id.	1859	*id.*
126	*Atretia*	Jeffreys	1871	?



It cannot be doubted that a certain number of these genera when better understood will require to be added to the synonyms. It will be so especially with some that appear founded more on specific than generic characters. The families to which several of the genera belong cannot yet be correctly determined.

affinities of the Brachiopoda, or the exact position the group should occupy in the animal kingdom. The Invertebrata have been grouped into five sub-kingdoms, namely, the *Protozoa*, *Cœlenterata*, *Annuloida*, *Annulosa*, and *Mollusca*, and for many years the Brachiopoda have been considered to constitute a separate class in the sub-kingdom Mollusca, a view still maintained by some distinguished naturalists. Milne-Edwards, some years back, separated the Mollusca into two divisions, *Mollusca* and *Molluscoida*, and into the last division he placed the *Brachiopoda*, *Polyzoa*, and *Tunicata*, an arrangement that has been followed by many naturalists. Although the greater number of zoologists have admitted the close connexion existing between the *Polyzoa* and *Brachiopoda*, some considerable doubt has been expressed with respect to the affinities and position of the latter to the *Tunicata*. Moreover, a strenuous effort has been made by such excellent observers as Steenstrup, Morse, Kowalevsky, and Alex. Agassiz to demonstrate that the affinities of the Brachiopoda and Polyzoa are with the worms, and that they should form a division, or two divisions, of the Annulosa, and be placed close to the Annelids.

In his review of Kowalevsky's admirable memoir on the embryology of *Argiope*, *Thecidium*, and *Terebratula*, Alex. Agassiz observes: "The close relationship between the Brachiopoda and Bryozoa (Polyozoa) cannot be more fully demonstrated than by the beautiful drawings upon plate v. of Kowalevsky's history of *Thecidium*. We shall now have at least a rational explanation of the homologies of Brachiopods; and the transition between such types as *Pedicellina* to *Membranipora* and other incrusting Bryozoa is readily explained from the embryology of Thecidium. In fact, all incrusting Bryozoa are only communities of Brachiopods, the valves of which are continuous and soldered together, the flat valve forming a united floor, while the convex valve does not cover the ventral valve, but leaves an opening more or less ornamented for the extension of the Lophophore."

With respect to the *Tunicata* we are reminded by Morse, that Kowalevsky, Kupffer, Schultze, and others, assign to them a position at the base of the Vertebrate series, through the affinities of some of their forms to *Amphioxus*, as well as their singular embryological relations to the Vertebrates. Gratiolet states likewise that the Tunicata are in no way related to the Brachiopoda, and Hancock, in 1870, expressed himself to me as follows, "Of late years I have gradually inclined to the opinion that the Brachiopoda are not so closely related to the Tunicata as we at one time thought. I am now busily engaged in working out the Tunicata, and they seem to be very intimately connected with the Lamellibranchs. I am disposed to consider that there is a considerable hiatus dividing the Tunicata from the Brachiopoda and the Polyzoa or Bryozoa, and that these two latter groups alone should be included in the *Molluscoida*. If therefore Morse can establish his doctrine, it will relieve me of some little difficulty, inasmuch, as it will militate against Huxley's view that the branchial sac of the *Ascidian* is the homologue of the pharynx of the Polyzoa. My idea being that the branchial sac is the true representative of the gill plaits of the Lamellibranch, and has nothing to do with the pharynx of the Bryozoon. There are some characters of the Brachiopoda that are very puzzling." It is therefore evident that the dismemberment of the Molluscoida must be considered necessary, and that we cannot place the *Brachiopoda* and *Polyzoa* in the same division with the *Tunicata.*

The Brachiopoda have likewise been considered by Gratiolet, and some others, to be allied to the Crustacea. Morse reminds us also that twenty-six or twenty-seven years ago Prof. Steenstrup had not only considered the Brachiopoda as worms, but had placed them near the tubicular annelids.

It would not be possible, in this short paper, to enter into the numerous and elaborate details given by those zoologists in support of their views, and the reader must consequently refer for more ample information to Prof. Morse's several memoirs upon the subject, and especially to the one on "the systematic position of the Brachiopoda" published in the Proceedings of the Boston Society of Natural History, vol. xv., 1873, as well as to Kowalevsky's important memoir published in 1875. This last, however, written in the Russian language, not being accessible to every reader, I cannot do better than reproduce the short review published by A. Agassiz in Silliman's *American Journal of Science and Art* for 1874. "The second memoir of Kowalevsky is a very complete history of the development of Brachiopods, strikingly in accordance with the views of Steenstrup, and of Morse, on the affinities of the Brachiopods with Annelids. The homology between the early embryonic stages of *Argiope* with the known annelid larvæ is most remarkable, and the resemblance between some of the stages of *Argiope* figured by Kowalevsky, and the corresponding stages of growth of the so-called Loven type of development among annelids is complete. The number of segments is less; but otherwise the main structural features show a closeness of agreement which will make it difficult for conchologists hereafter to claim Brachiopods as their special property. The identity in the ulterior mode of growth between the embryo of *Argiope*, and of *Balanoglossus*, in the Tornaria stage, is still more striking; we can follow the changes undergone by *Argiope* while it passes through its Tornaria stage, if we may so call it, and becomes gradually, by a mere modification of the topography of its organs, transformed into a minute pedunculated Brachiopod, differing as far from the Tornaria stage of *Argiope* as the young *Balanoglossus* differs from the free swimming Tornaria. In fact the whole development of *Argiope* is a remarkable combination of Loven's and of Tornaria types of development among worms. His paper also includes the history of a less vermiform type of development, that of *Thecidium*, and of *Terebratula*, in which the observations of Kowalevsky fully agree with the previous well-known memoir of Lacaze-Duthiers on *Thecidium*,[1] and of Morse on *Terebratulina*,[2] and it certainly is a striking proof of the sagacity of Morse to have announced so positively, from the history of the American Brachiopoda alone, the vermiform affinities of the Brachiopods now so conclusively proved by the development of *Argiope* in Kowalevsky's paper."

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[1] Annales des Sciences Naturelles, 4ème série, Zool. vol. xv. 1861.

[2] Memoirs of the Boston Society of Natural History, vol. ii.

No one can doubt that the Brachiopods and Amphitrites possess many important characters in common after perusing the admirable observations upon the subject contained in Prof. Morse's memoir; but, at the same time, as was remarked to me by Prof. Verrill, almost any invertebrate group may be annelidelized by overrating certain points of its affinities; and, it seems to me, that one must not place entire confidence in any classification which is founded to so great an extent on embryological characters. It may turn out, however, that the Brachiopoda *really* constitute a division of the Annelids. The setæ do not appear to be a constant character, and the tendinous peduncle of the Terebratulidæ seems very different from the annulated structure which Morse describes in *Lingula*, and it appears, according to Dr. J. Gwyn Jeffreys, to closely resemble the peduncle of a species of *Anomia* (*A. patelliformis*), *Lingula* being likewise an aberrant form.

Morse does not, however, fail to observe that "in considering the assemblage of remarkable characters in the Brachiopoda, we must recognize in them a truly ancient type. Thus, while we do not find them in all their characters resembling any group of worms, I have endeavoured to show that all their features, to a greater or lesser degree, are shared by one or other of the various groups of the Vermes, with one or two features of the Arthropods."

Morse concludes his elaborate series of observations by stating that he must regard the Brachiopoda as *ancient cephalized Chætopods*, while *Serpula*, *Amphitrite*, *Sabella*, *Protula*, and others, may be regarded as modern (later) *cephalized Chætopods*.

Mr. Dall, a distinguished American naturalist, is strongly opposed to the idea of placing the Brachiopoda among the Annelids, and in order that the reader may become acquainted with both sides of the question, we must refer him to Dall's paper in the *American Journal of Science* for 1871. Therein he maintains, after a lengthened comparison between the Annelids and Brachiopoda, that these last are allied to the other groups included in the *Molluscoida*, and through their combined characters to the typical Mollusca. Stoliczka agrees with the conclusions advocated by Dall, and adds, "There cannot be, I think, much doubt as to the true Molluscous character of the Brachiopoda, and their proper classification between the *Anomiidæ* of the Pelecypoda, and the Saccopoda, and the arm-bearing section of the Ciliopoda." [1]

With such contradictory views as have here been briefly announced, it seems still premature to emit a positive opinion with respect to the affinities of the Brachiopoda, notwithstanding the mass of most valuable information so ably contributed to science by Morse, Kowalevsky, Dall, and others. The following observations on the affinities of the Brachiopoda have been kindly communicated to me by Prof. W. King, Sc.D.:—

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[1] Palæontologia Indica, Brachiopoda, vol. iv. 1872.

"The group *Palliobranchiata* embraces forms formed of two types of organization. The absence of an anal vent in the Clistenterata makes them inferior to the aniferous Tretenterates. In determining the affinities of the group first thoughts should be directed to the simplest of these divisions: but a difficulty arises; for, so far as is known, the second and highest division was the first that made its appearance. This, however, may be got over on the supposition that the Tretenterates became degraded into the Clistenterates,—such a metasmotosis is not unknown; for example, the ventless Ophiurids are outcomes of aniferous pluteiform larvæ, and probably a similar metasmotosis takes place in certain ventless asteroids (*Astropecten*, *Luidia*, etc.). Adopting this supposition, the Clistenterates may be dismissed from further consideration. I shall, therefore, regard the Tretenterates as the initial or older type. The Cambrian system is not only the first in which indisputable organic remains occur, but it is the one in which the Palliobranchs make their first appearance, and, as far as is known at present, they appear to be exclusively Tretenterates; the genera, with perhaps one exception[1] (*Orthis Hicksii*), being all more or less related to *Lingula* and *Discina*. Associated with these Cambrian Tretenterata there are remains of organisms belonging to other groups besides the Palliobranchs. According to the doctrine of Chronogenesis, the natural affinities of any group of organisms can only be determined by its structural characters being considered in connexion with those of other groups of contemporaneous (geological) origin,[2] I shall attempt to give a table of the Cambrian fossils of interest in connexion with the present subject, separated into their respective groups, which I have drawn up from Hicks's momoir on the Tremadoc rocks in the neighbourhood of St. Davids, in South Wales:[3]—

Protospongia	Spongida.
Oldhamia	? Hydrozoa.
	? Polyzoa.
Theca	? Pteropoda.
Lingulella, etc.	Palliobranchiata.
Palasterina	Asteridia and Ceptoidia.
Histioderma, *Scolithus*	Annelida.
Paradoxides, *Agnostus*, etc.	Crustacea.

Of these groups the Palliobranchs have often been associated with *Polyzoa*; but lately Morse has endeavoured to show that they are more closely related to one of the others, *Annelida*. There is no doubt he has succeeded in adducing certain points in his favour; but there are so many dissimilarities between the annelids and the palliobranchs that it is scarcely to be expected the polyzoonal alliance will be abandoned by those who have contended for it, especially since the discovery of *Rhabdopleura*, a marine form of Hippocrepian polyzoa.[4] There is another group of organisms, also occurring in Cambrian rocks, which does not appear to have attracted much notice in connexion with the subject in hand—I allude to the *Asteridia*. The late Johannes Müller showed that in the larval state certain star-fishes have their form completely different from what it is in the adult state, changing from bilateral to a radical character. This is especially the case with the larval star-fish (*Bipinnaria asterigera*), which possesses features strongly reminding one of the structure of *Lingula*. It has a large peduncular appendage at the posterior end of the body; it is furnished with a pair of tentaculiferous arms bilaterally arranged, with the tentacles ciliated; its mouth is situated between and at the base of the arms; it has an intestine, which is doubled back on itself, and terminates at one side as an open gut.[5] This seems so very like the general structural plan of *Lingula* that I prefer associating the Tretenterates with the larval star-fish, rather than with the annelids in a similar stage, or the adult forms of polyzoons. The latter seem to be more removed from the Tretenterates than the annelids. Chronogenesis, though it appears to tell equally in favour of Morse's view, may be held as favourable to the Asteridian affinities of the Palliobranchs; for notwithstanding that *Palasterina Ramseyensis* occurs in a higher horizon of the Cambrian system than the annelids of the Longmynds, Hicks mentions, in a note appended to his description of the above species, that Torrell and Linnarsson have described forms of a Star-fish from Swedish rocks, supposed to be of the Harlech or Longmynd group of the Lower Cambrian. Although admitting that the palliobranchs manifest affinities to the annelids, polyzoons, and asterids, I cannot relinquish the idea that they are more closely related to the molluscs. If they do not possess sufficiently distinctive characters entitling them to rank as a more comprehensive division, I would, instead of associating them with any of the first three groups above mentioned, prefer that they retain their old position in the sub-kingdom *Mollusca*, as defined by Cuvier."

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[1] An *Orthis* (possibly a Clistenterate) has been found in the Menevian group, but to whatever division it may belong does not matter, as *Lingulella* occurs at the base of the Cambrians.

[2] See a memoir by Prof. King, entitled, "An Attempt to Classify the Tetrabranchiate Cephalopods." Annals of Natural History, in 1845.

[3] Quart. Journ. Geol. Soc. vol. xxix. 1872.

[4] First described by Prof. Allman (Quart. Journ. Microscopical Science, n. s. vol. ix. p. 57), next Ossian Sars (id. n. s. vol. xiv. p. 1), previously Ray Lankester has published some valuable "Remarks on the Affinities of Rhabdopleura" in the same work, id p. 77.

[5] Joh. Müller, Ueber die Larven und die Metamorphose des Echinoderm, p. 22, Taf. 2, fig. 1, 1849.

I am, however, quite of opinion that, whether the Brachiopods be placed in a separate group close to the Mollusca, or to the Annelids, they possess sufficient characters of their own to constitute a well-defined class.

Distribution in Time.

Assuming that the reader is acquainted with the geological divisions into which the crust of this earth has been grouped, I may at once observe, as justly remarked by Barrande, in his admirable memoir, "Epreuves des Théories Paléontologiques par la realité," that the Brachiopoda, after the Trilobites, occupy the most important place in the Cambrian or Primordial fauna. Thus in 1871, out of 241 species known to him as composing the animal kingdom of that period, 179 are referable to the Trilobites and other Crustaceans, 28 to the Brachiopoda, while 34 species would be divided between the Annelides, Pteropodes, Gasteropoda, Bryozoa, Cystidians, and Spongida. Subsequent to these researches several additional species of Trilobites and Brachiopoda have been added to the list through the indefatigable exertions of Prof. Linnarsson, Mr. Hicks, and others. If therefore we exclude the problematical "Eozoon Canadense" from the animal creation, as some naturalists have done,[1] we find the Brachiopoda along with the groups mentioned by Barrande as the earliest representatives of life at present known; for Mr. Hicks has obtained undoubted examples of *Lingula* or *Lingulella* (*L. primæva*) from the very base of the whole Cambrian series of St. Davids in Wales.

It is impossible, for the present, to offer more than an approximate comparison, based on numbers, of the genera and species that have existed during the various and more or less extended geological, periods; and many years will have to pass away before some master minds will be able to grapple with the accumulated observations of a century or more, and reduce the number of genera and species within reasonable limits, from which something like trustworthy data may be formed. Much, indeed, of the confusion must be attributed to the imperfection of the information still existing on zoology and comparative anatomy, so essential to the proper understanding of fossil, or extinct genera and species.

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[1] Dawson, Carpenter, Rupert Jones, and others, consider *Eozoon* to be a Rhizopod or Foraminifer; while King, Rowney, Carter, and others, firmly maintain that it is a mineral production.

But to return to our subject. I cannot do better than to extract from Lyell the following passage. "Nothing is more remarkable, in the Silurian strata generally of all countries, than the preponderance of the Brachiopoda over other forms of Mollusca. Their proportional numbers can by no means be explained by supposing them to have inhabited seas of great depth, for the contrast between the palæozoic and the present state of things has not been essentially altered by the late discoveries made in our deep-sea dredgings. We find the living Brachiopoda so rare as to form about one forty-fourth of the whole bivalve fauna, whereas in the Lower Silurian rocks, and where the Brachiopoda reach their maximum, they are represented by more than twice as many species as the Lamellibranchiate bivalves. There may, indeed, be said to be a continuous decrease of the proportional number of this lower tribe of Mollusca as we proceed from the older to the newer rocks."

Dr. Bigsby informs me that from a conspectus in his new Thesaurus (now in the press) the following numbers of Silurian, Devonian, and Carboniferous Brachiopoda have been given, with due regard to accuracy, but that after all it is only a careful approximation liable to future disturbances:

	America.	Europe, etc.	Total.
Cambrian and Silurian	689	733	1422
Devonian	577	789	1366
Carboniferous	488	384	871
	1754	1905	3659

The number from the Permian formation, which completes the Palæozoic series, has not yet been computed, but they are comparatively few in number. Making a large allowance for synonyms, it will be seen that fully 3000 species are already known to have existed during the primary periods. It is also a remarkable fact that the Brachiopoda, so immensely abundant during the Cambrian, Silurian, Devonian, and Carboniferous periods, became apparently very much less numerous during the Permian and Triassic; while they again became abundant, although comparatively reduced in number, during the Jurassic and Cretaceous period. In the Tertiaries they had materially decreased in number, and are represented, at the present time, by about one hundred species. It has also been clearly ascertained that a certain number of genera and species passed from one system or formation into the one that followed it, as may be seen by a glance at the Table, in which the general distribution of the genera in time has been given with as much accuracy as the present state of our knowledge will admit. From this table it will be perceived that about 9 genera appeared for the first time in the Cambrian system, 52 in the Silurian, 21 in the Devonian, 7 Carboniferous, 2 Permian, 2 Triassic, 11 Jurassic, 5 Cretaceous, 3 Tertiary, and 9 in the recent periods.[1] But what wonderful changes have been operating during the incalculable number of ages in which the creation (?) and extinction of a large number of genera and thousands of species have taken place. Some few only of the primordial, or first created genera, such as *Lingula*, *Discina*, and *Crania*, have fought their way and struggled for existence through the entire sequence of geological time. Many were destined to a comparatively ephemeral existence, while others had a greater or lesser prolongation of reproduction. These remarks lead me to give some extracts from a letter which I received from Darwin as far back as the 26th of April, 1861. In that letter, this eminent and admirable observer writes, "I do not know whether you have read my 'Origin of Species.' In that book I have made the remark, which I apprehend will be universally admitted, that as a whole, the fauna of any formation is intermediate in character between that of the formation above and below. But several really good judges have remarked to me how desirable it would be that this should be exemplified and worked out in some detail, and with some single group of beings. Now every one will admit that no one in the world could do this better than you with Brachiopods. The result might turn out very unfavourable to the views which I hold; if so, so much the better for those who are opposed to me. But I am inclined to suspect that on the whole it would be favourable to the notion of descent with modification. I can hardly doubt that many curious points would occur to any one thoroughly instructed in the subject, who could consider a group of beings under the point of view of descent with modification. All those forms which have come down from an ancient period very slightly modified ought, I think, to be omitted; and those forms alone considered which have undergone considerable change at each successive epoch. My fear is whether the Brachiopoda have changed enough. The absolute amount of difference of the forms in such groups at the opposite extremes of time ought to be considered, and how far the early forms are intermediate in character between those which appeared much later in time. The antiquity of a group is not really diminished, as some seem to think, because it has transmitted to the present day closely allied forms. Another point is how far the succession of each genus is unbroken from the first time it appeared to its extinction, with due allowance made for formations poor in fossils. I cannot but think that an important essay (far more important than a hundred literary reviews), might be written by one like yourself, and without very great labour."

In several subsequently written letters, Darwin reiterates his suggestions. I can assure you that I have not neglected a request coming from so eminent a quarter, but I am bound to state that I have found the subject beset with so many apparently inexplicable difficulties, that year after year has passed away without being able to trace the descent with modification among the Brachiopoda which the Darwinian doctrine requires.

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[1] These numbers must of course be considered provisional, see Table.

The imperfection (one due, I believe, to our slight acquaintance with the subject) in the geological record cannot in many cases be doubted, but we have no right to make capital out of unknown data. We must therefore deal with facts as we find them, and see how far they will bear upon the subject under examination. It may be quite true, that strata at great distances cannot be positively asserted to be strictly speaking absolutely contemporaneous, although they may contain the same animals.

Prof. Huxley has stated that for anything that Geology and Palæontology are able to show to the contrary, a Devonian Flora in the British Islands may have been contemporaneous with a Carboniferous Flora and Fauna in Africa; but as we have no certainty that such has been the case, it cannot be adduced in support of the theory under notice. It is likewise very probable that some species may have migrated from the sea-bottom on which they originally lived to some more favourable locality, and have become to some extent modified. No one can seriously doubt that life has continued to be represented under one form or another ever since it was first brought into existence, and I consequently cannot agree with M. Deshayes and others who believe in a total extinction of the animal creation at certain specified periods. We are also aware that, taking, for instance, the rocks of the Carboniferous period, in almost every locality in Europe, Spitzbergen, Newfoundland, America, India, or Australia, there are present a few species common to all, in addition to a number that are special to the locality. Thus, for example, as I have shown elsewhere, *Spirifer lineatus* is one of those persistent forms, but with different proportions according to the locality, caused, no doubt, from the sea-bottom being more or less favourable to its development. It is consequently very large in the Punjab, of moderate dimensions in Europe, and considerably dwarfed in Nova Scotia. Still the species remain essentially the same.[1]

Notwithstanding the theoretical doctrine that has been promulgated with respect to the origin of species, we are still and shall probably for ever remain in the dark, or within the region of suppositions, with respect to so important a question. In his admirable address to the Belfast Meeting of the British Association, Tyndall observes: "If you ask me whether there exists the least evidence to prove that any form of life can be developed out of matter, without demonstrable antecedent life, my reply is that evidence considered perfectly conclusive by many has been adduced; and that were some of us who have pondered this question to follow a very common example, and accept testimony because it falls in with our belief, we also should eagerly close with the evidence referred to. But there is in the true man of science a wish stronger than the wish to have his beliefs upheld; namely, the wish to have them true. And this stronger wish causes him to reject the most plausible support, if he has reason to suspect that it is vitiated by error. Those to whom I refer as having studied this question, believing the evidence offered in favour of 'spontaneous generation' to be thus vitiated, cannot accept it. They know full well that the chemist now prepares from inorganic matter a vast array of substances which were some time ago regarded as the sole products of vitality. They are intimately acquainted with the structural power of matter as evidenced in the phenomena of crystallization. They can justify scientifically their belief in its potency, under the proper conditions, to produce organisms. But in reply to your question they will frankly admit their inability to point to any satisfactory experimental proof that life can be developed save from demonstrable antecedent life." Further on he adds, "In fact, the whole process of evolution is the manifestation of a Power absolutely inscrutable to the intellect of man."

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[1] It has been observed by Robert MacAndrew that although the size attained by Mollusca (and no doubt by other animals) may be influenced by various conditions in different localities, as a general rule each species attains its greatest size, as well as its greatest number, in the latitudes best suited to its general development; and that whether a species be Arctic, Boreal, Celtic, or Lusitanian, it will grow largest in the region to which it belongs.

Darwin's tempting and beautiful theory of descent with modification bears a charm that appears to be almost irresistible, and I would be the last person to assert that it may not represent the actual mode of specific development. It is a far more exalted conception than the idea of constant independent creations; but we are stopped by a number of questions that seem to plunge the conception in a maze of inexplicable, nay, mysterious difficulties; nor has Darwin, as far as I am aware, said how he supposes the first primordial form to have been introduced. The theory is at best, as far as we can at present perceive, with our imperfect state of knowledge, but half the truth, being well enough in many cases as between species and species; for it is evident that many so-termed species may be nothing more than modifications produced by descent. It applies, likewise, to accidental variations as between closely allied genera, yet there is much more than this, with respect to which the theory seems insufficient. The strange geological persistency of certain types, such as of *Lingula, Discina, Nautilus*, etc., seems also to bar the at present thorough acceptance of such a theory of general descent with modification. Barrande seems to be strongly opposed to the Darwinian view, for in his admirable memoir already quoted he states: "Par contraste nous devons constater, comme resultat final de nos études, que l'observation directe contredit radicalement toutes ses prévisions des théories paléontologiques au sujet de la composition des premières phases de la faune primordiale Silurienne. En effet, l'étude speciale de chacun des éléments zoologiques qui constituent ces phases, nous a démontré, que les prévisions théoriques sont en compléte discordance avec les faits observés par la paléontologie. Ces discordances sont si nombreuses, et si prononcées que la composition de la faune réelle semblérait avoir été calculée a dessin, pour contredire tout ce que nous enseigne les théories, sur la première apparition et sur l'evolution primitives des formes de la vie animale sur le globe."

We have no positive evidence of those modifications which the theory involves, for types appear on the whole to be permanent as long as they continue, and when a genus disappears there is no modification, that I can see, of any of the forms that continue beyond, as far as the Brachiopoda appear to be concerned, and why should a number of genera, such as *Lingula, Discina, Crania,* and *Rhynchonella,* have continued to be represented with the same characters and often with but small modification in shape during the entire sequence of geological strata? Why did they not offer modifications or alter during those incalculable ages? Limiting myself to the Brachiopoda, let us see what further they will tell us upon this question. Taking the present state of our knowledge as a guide, but admitting, at the same time, that any day our conclusions and inductions may require to be modified by fresh discoveries, let us ascertain whether they reveal anything to support Darwinian ideas. We find that the larger number of genera made their first appearance during the Palæozoic periods, and since they have been decreasing in number to the present period. We will leave out of question the species, for they vary so little that it is often very difficult to trace really good distinctive characters between them; it is different with the genera, as they are, or should be, founded on much greater and more permanent distinctions. Thus, for example, the family *Spiriferidæ* includes genera which are all characterized by a calcified spiral lamina for the support of the brachial appendages; and however varied these may be, they always retain the distinctive characters of the group from their first appearance to their extinction. The Brachiopodist labours under the difficulties of not being able to determine what are the simplest, or which are the highest families into which either of the two great groups of his favourite class is divided; so far then he is unable to point out any evidence favouring progressive development in it. But, confining himself to species, he sees often before him great varietal changes, so much so, as to make it difficult for him to define the species; and it leads him to the belief that such groups were not of independent origin, as was universally thought before Darwin published his great work on the Origin of Species. But in this respect the Brachiopoda reveal nothing more than other groups of the organic kingdoms.

It would appear that the earliest forms among the Brachiopoda are referable to the division *Tretenterata,* which includes the genera *Lingulella, Lingula, Discina,* and *Obolella.* Of these only *Lingula* and *Discina* have lived on with but slight modifications in external shape during the entire sequence of geological time; and they are still represented by several species. But in rocks somewhat later in age (from the middle beds of the Menevian group or Lower Lingula flags) to those in which the above genera are found, there occurs a species of *Orthis* (*O. Hicksii*), which may possibly be the first representative, as far as we are aware, of the division *Clistenterata.* On this point, however, I would refer to Professor King's note previously given. Since the Cambrian period both divisions continue to be represented without apparently showing a tendency to pass one into the other. Now although certain genera, such as *Terebratula, Rhynchonella, Crania,* and *Discina,* have enjoyed a very considerable geological existence, there are genera, such as *Stringocephalus, Uncites,* *Porambonites, Koninckina,* and several others, which made their appearance very suddenly and without any warning; after a while they disappeared in a similar abrupt manner, having enjoyed a comparatively short existence. They are all possessed of such marked and distinctive internal characters that we cannot trace between them and associated or synchronous genera any evidence of their being either modifications of one or the other, or of being the result of descent with modification. Therefore, although far from denying the possibility or probability of the correctness of the Darwinian theory, I could not conscientiously affirm that the Brachiopoda, as far as I am at present acquainted with them, would be of much service in proving it. The subject is worthy of the continued and serious attention of every well-informed man of science. The sublime Creator of the Universe has bestowed on him a thinking mind; therefore all that can be discovered is legitimate. Science has this advantage, that it is continually on the advance, and is ever ready to correct its errors when fresh light or new discoveries make such necessary.

The importance of the study of the Brachiopoda must be obvious to all. They are among the first well-known indications of life in this world; and they have continued to be very extensively represented up to the present time. They are also very characteristic fossils, by which rocks at great distances, whether in New Zealand or Spitzbergen, in the Himalayas or the Andes, can be identified without its being even necessary for the palæontologist to visit the district from whence the fossils are derived. They are, as Mantell would have termed them, sure medals of creation, the date of their appearance firmly stamped upon them, and their distinctive characters so legibly impressed as to defy misinterpretation.

IV.—ON MR. HELLAND'S THEORY OF THE FORMATION OF CIRQUES.

By the Rev. T. G. BONNEY, M.A., F.G.S.;
Fellow, and late Tutor, of St. John's College, Cambridge.

IN the Quarterly Journal of the Geological Society (vol. xxxiii. p. 142) is an important paper by Mr. Helland, on Fjords, Lakes, and Cirques in Norway and Greenland. In this he notices a theory of mine on the formation of cirques which was published in the same journal (vol. xxvii. p. 312). As I mentioned in a note attached to his paper, he somewhat misunderstands me, supposing apparently that I describe only cirques of a small size,—the fact being, that, so far as I know, the Alpine cirques are quite commensurate with those of Norway. This, however, is of slight importance. My present purpose is to give reasons why, after further observations in the Alps and Pyrenees, and even in the British Isles, I still prefer the explanation then advanced, that the cirques are mainly produced by the combined erosive action of streamlets, to the one given by Mr. Helland, that a cirque is a result of glacial action.

I must first remark that in the Alps the persistency in direction, which he observes in the Norway and Greenland cirques, is not